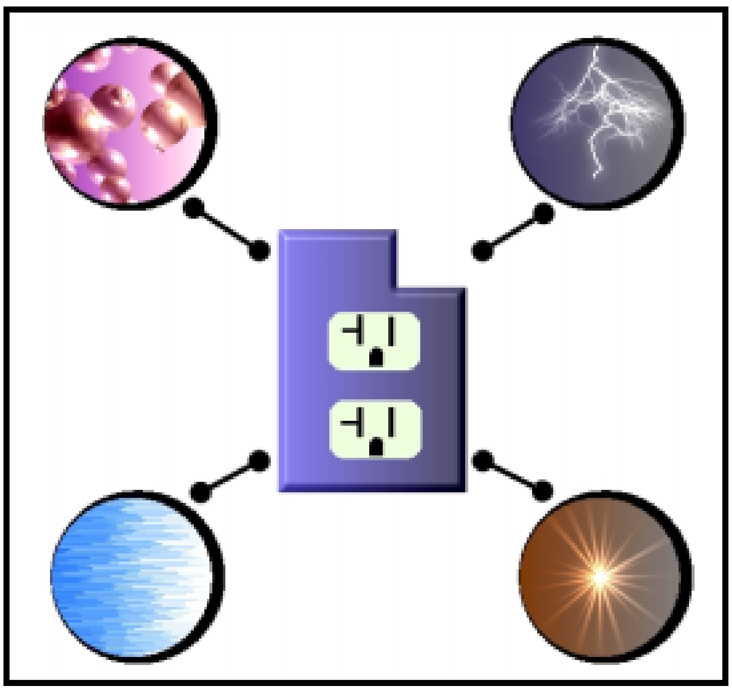
June 2001

UTAH TECHNOLOGY REPORT

ALTERNATIVE ENERGY



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<u>Executive Summary</u>

Alternative Energy—Powering Utah's High-Tech Future

"Over the next fifteen years, the electric power sector will emerge as the most dynamic and rewarding global investment class. Fundamental shifts in power technology are combining with a structural revolution in power markets to bring new and exciting opportunities to what has become, in the last 50 years, a staid, dividend-oriented class of investments."

Reed Wasden Research
In *Prometheus Unbound*, 2000

Introduction

Energy has risen in the last couple months to be America's most salient political and economic issue. Whether California's rolling blackouts, the Nation Energy Policy, new power plant construction, electricity price caps, gas price hikes, or power crunches in places as far away as Brazil or Southeast Asia, everyone from Washington politicos to western CEO's wants to own a piece of the energy issue. And exactly who ends up "owning" energy will dictate the future of energy policy.

This report will highlight the urgency with which Utah must act towards energy policy and energy providers, as well as with respect to developing energy technologies. Much of that urgency comes from the market forces alive for a limited time in each segment of the alternative energy industry, and as we will also show, much of Utah's future in alternative energy will depend on our ability to recruit the companies listed herein. We will show that it is imperative that Utah act quickly to secure a place in the future of energy development and technology.

We also contend that Utah's energy future must include traditional power—coal-fired power plants in particular—in order to keep Utah a viable location for the development of the energy-intensive high-tech sector of the economy.

We offer here a summary of the report, our findings, and recommendations.

Research Methods

Our research methods included the following:

- The team researched financial and other corporate information using various Web financial reporting resources, as well as company Websites.

- Information on the various technologies discussed herein was researched using government, industry, and research institution Web resources and data. We reviewed national research on the industry, as well as data and findings on alternate energy technology.
- We conducted interviews with corporate leaders and university researchers on the viability of the alternative energy industry in Utah in general, and about the viability of each of the technologies specifically. We targeted all Utah university researchers with expertise in any area related to alternative energy.
- We conducted an international, Web-based survey of 143 alternate energy industry CEOs and Vice Presidents. The Alternative Energy Corporate Location Factors Survey was designed to help us assess what key corporate decision maker look for in selecting a location for their operations. We selected the potential respondents using industry organization membership lists, corporate Websites, and a database of energy industry companies to locate qualified respondents. We received a 17 percent response rate. A copy of the survey is included in the appendix to this report.

Findings

General Findings

The following findings are related to developing a high-technology alternative energy sector in Utah, and to supporting other high-technology ecosystems in Utah.

Deregulation

- In order for alternative energy generation and transmission technologies to be viable on a large commercial scale, various technical and regulatory issues must be resolved.
- While many of the technologies are currently commercially viable (wind, solar, microturbines, stationary fuel cells), deregulation of access to electricity grid wires is necessary to encourage grid connection, and to encourage interconnection of independent power generators and on-site generators to the grid.
- Deregulation of the industry would decrease big power's incentives to over-invest in generation capital, and instead, invest in new capacity.
- Restructuring the industry will encourage a diverse portfolio of energy generation technologies to be used. As competition increases, power companies will diversify their services, offering products from renewable, distributed, and high-tech sources.
- Deregulation will fuel investment in high-tech research, by increasing incentives to innovate and bring down costs.
- The California power crisis has highlighted the wrong way to deregulate. Political opposition to deregulation has been fueled by California's problems, but these problems should not deter Utah and other states considering deregulatory

action from pursuing wise-headed deregulatory and restructuring measures, including well-monitored wholesale and retail markets for power, long-term contracts for power provision to stabilize power prices and supply, well-designed capital divesture provisions, and especially public ownership/non-discriminatory access of the transmission grid.

Costs

- Capital plus installation costs for traditional power plants is in the area of $250.00 to $400.00 per kW of generation capacity, depending on the size of the plant and whether the plant is fueled by coal, nuclear, hydro, or natural gas.
- Operations costs for coal-fired plants are very low, although maintenance, which is long and expensive, is not included in the estimates. Hydro plants are the cheapest, cleanest form of power generation. Gas-fired power plants are expensive to operate because of the rising costs of natural gas fuel.
- Capital costs for alternative energies are not competitive with traditional power plants. Microturbines are the cheapest alternative to traditional generation, and cost about $800.00 per kW of generation capacity. Solar cells are the most expensive alternative to traditional generation, and cost about $4500.00 per kW of generating capacity.
- Operations costs of alternative energy generation is its strongest benefit. Since most run on natural gas, and use the gas more efficiently than traditional gas-fired power plants, operations tends to be cheaper than traditional gas-fired generation. Options like hydro, wind, geothermal, and solar power (renewables) run with very few operations costs. Maintenance on many of these technologies is comparable to that required by traditional power plants, but fuel cells and microturbines are low-maintenance alternatives. Solar panels require no mainenance.
- Until costs per kW of generation capacity are competitive with traditional grid power generation, alternative energies will be produced for niche markets. The niche markets will develop around issues other than cost: power quality, reliability, back-up generation, on-site generation, distributed generation, “green” power, off-grid power, isolated domestic areas and lesser developed regions, high-value/energy-intensive industry processes.

Utah’s Resources

- The Olympics provide a great opportunity to showcase our alternative energy capabilities, our adequate power supply, and our environmental awareness.
- Utah has inadequate to moderate academic, research, commercial, and production resources in certain alternative energy technologies.
- Utah’s research and development of alternative energy lags behind that of other states in all areas except biomass (renewable) and solid oxide fuel cells.
- The University of Utah and Brigham Young University are the world centers for combustion research and development. Specializing in coal, natural gas, and biomass combustion, the two universities have developed ways to burn coal with

fewer emissions, and have developed more efficient and environmentally friendly processes and combustion technologies.

- Eighteen percent of Utah mining activity comes from the coal industry. Three thousand Utahans are employed in the coal industry. Coal-generated power makes up over 90 percent of the power used in Utah industry and residences. Utah's largest power monopoly, Utah Power and Light (Pacificorp) enjoys a good relationship with its Utah customers.
- The coal-fired power industry is entrenched in Utah culture and economics.

Distributed Generation

- Distributed generation refers to power generated either by or close to users. It includes off-grid, on-site, back-up, and grid-interconnected power.
- Distributed generation technologies include stationary fuel cells, microturbines, small gas-fired power plants built close to users, and solar generators.
- Distributed generation represents a current trend with a bright future. Investment in distributed power generation has increased by $780 million dollars in the last seven years.
- The California power crisis has highlighted the importance of reliable power. Distributed generation offers a way for high-value and power-intensive production processes and business to continue uninterrupted by power supply shortages and bottlenecks.
- Distributed generation can relieve the burden on the grid, freeing up transmission capacity and decreasing the amount of power required by energy intensive industries. It also produces electricity for the grid when interconnected properly.
- Currently, grid interconnection is the main technical and regulatory problem for expanding the distributed generation industry.

Technologies

Associated with alternative energy technologies we researched are findings specific to each technology.

Renewables

Solar

- Utah is in a good position to become a leader in the solar power industry. The technology used to produce solar products and semiconductors is essentially the same. Utah already has strong capabilities in the production of semiconductors.
- Utah has plenty of sun.
- Solar power is very costly—not cost-competitive with other energy sources. Costs are not expected to decline to make solar

Wind

- If all Utah's wind power capacity were developed with large-scale wind technology, wind could supply 171 percent of Utah's current electricity consumption.
- Wind technology is costly, but the costs have dropped 80 percent over the last 20 years. The costs may continue to become more competitive with tradition generation.
- Utah is currently conducting wind experiments with the DOE.

Geothermal

- Utah has two geothermal generation sites, one in Milford and another in Cove Fort. These are the only two sites where geothermal generation is feasible.
- The Milford site may have additional untapped generation capacity.

Hydro

- Utah has developed all of its politically feasible hydro capacity, and most of its technically and environmentally feasible hydro capacity.
- Hydro power is very inexpensive to produce, compared to other forms of alternate energy and tradition energy.

<u>Microturbines</u>

- Microturbines are the most cost-effective and marketable form of small distributed generation currently available.
- Microturbines are small jet engines that run on natural gas and produce power and heat for buildings and other small applications.
- Costs of microturbines are expected to decrease by 40 percent over the next 20 years. Microturbines are not currently cost-competitive with traditional generation.
- The microturbines market is centered around reliability and need for on-site and back-up power systems. Their cost competitiveness with other distributed generation technologies is the only relevant cost comparison.
- Microturbines cost less in terms of capital/installation than other distributed and alternative energy technologies. Their operations costs are competitive, since they run on natural gas.
- Investment in microturbines is increasing.
- Microturbines will continue to gain higher percentages of the distributed generation market through 2020.

Fuel Cells

- Fuel cells generate electricity, using hydrogen as the fuel. Hydrogen is the most abundant element on earth.
- Fuel cells are 30 – 90% efficient, much greater than the internal combustion engine running on gasoline.
- Fuel cells can allow power generation independent of the power grid.
- Fuel cells are too expensive to achieve mainstream adoption in the market. Costs cannot come down until production increases, production cannot increase until demand increases through lower costs, and the cycle continues.
- Most of the processes to make hydrogen consume more energy than is eventually available in the hydrogen. Although fuel cells are efficient, an efficient way to produce and store hydrogen has yet to be developed.
- Distributing hydrogen to consumers for use in fuel cells will require a whole new infrastructure.
- Commercialization of fuel cells is being driven by coalitions comprised of fuel cell developers, oil companies, automakers, government agencies, and academic institutions.
- Utah has a small presence in the fuel cell industry and is not part of any major coalition or industry group.
- Utah's fuel cell companies have a technology development focus, but not a product-oriented marketing focus.

Superconductors

- Superconductors are in the process of being developed for electricity grid applications
- The development of superconductors for use in electricity grid applications is in the pilot project stage.
- The cost of installing and maintaining superconductors is still very high.
- While the cost is still high, the realizable energy saving outweigh the costs.
- Superconductor components for electricity grids in the short run will be used in niche markets. Large utility companies in large metropolitan companies will be the first to adopt this technology. In the long run most utility companies will use superconductors for transmission, generation and the stabilization of electricity services.
- The cost of superconductor material is dropping as private and public researchers strive to lower superconductor costs.
- More research needs to be done in the field of cryogenics to lower the cost of keeping superconductor below the critical temperature. Superconductor research and development is moving forward quickly. Cryogenics research needs to move forward at the same pace.
- Utah has very few superconductor researchers.

- Utah has no companies researching and developing superconductors.
- Utah most likely is not positioned to become a leader world in the superconductor industry.

Recommendations

General Recommendations

Deregulation

- Utah should renew its investigation of feasibility of deregulatory legislative action.
- In order to stimulate growth in both the supply of electricity and the alternative energy Utah industry in Utah, as well as provide power to the energy-intensive high-tech industry, Utah must have more power. In order to create proper incentives for plant construction and industry development, we must deregulate.
- Deregulation should be carefully designed to avoid flaws present in California.
- Utah should take ownership of transmission grid, and provide non-discriminatory access to the grid by suppliers and producers.
- The state should deregulate the wholesale and retail power industry.
- The state should allow and require long-term contracts for power production, transmission, and distribution.

Costs

- Utah should strategically encourage research in alternative energy technology at its research institutions to continute development of cost-effective technology improvements. Research in enabling technologies, like hydrogen, cryogenics, and other non-existent technologies that will be the foundation for lowering the costs of alternate energy.
- Utah should avoid over-investment in the alternative energy industry, since we lack a solid industry and research foundation in alternative energy. Over-investment of money and political/policy resources in alternative energies will distract the state from developing adequate power resources for its future growth.
- Utah should employ tax incentive programs to lower the costs of research and development and use of alternative energy technologies.
- Demand-side policies work. Incenting the use of alternative energies (e.g., tax breaks for consumers who install solar cells or microturbines in their buildings) will raise demand for alternative energies, and increase industry incentives to develop more cost-effective technologies.

Utah’s Resources

- Utah’s power production competitive advantage is in coal. Therefore, the state should provide tax relief to power companies to incent new capacity construction.

Large coal-fired power plants are currently the most cost-effective and the quickest way to achieve economies of scale in the power industry.
- Utah should deregulate the industry, still providing for long-term transmission and distribution contracts to Utah power purchasers, and taking state ownership of the power lines.
- Utah should expand the Centers for Excellence Program's funding, incenting more valuable research and more capitalization of technology.
- Utah should study and improve its technology transfer process at its universities. The process is not spinning off technology as efficiently as it should.
- Utah's state universities should receive subsidies for funding top alternate energy researchers' salaries to attract and keep top research personnel.
- At the Olympics, Utah should offer an "Alternate Energy Technology Fair" to showcase alternative energy technology being developed in the state and to show the world that Utah is a power-rich and environmentally sensitive state.

Distributed Generation

- Utah must pass net-metering legislation allowing reimbursement for excess power generated by users that flows back out onto the grid.
- Eliminate cost-recovery penalties to those who use distributed generation technologies, until distributed generation is a significant (5 percent) portion of industrial electricity use.
- Utah may offer tax incentives to industrial consumers who choose to install distributed generation.
- Utah must increase the pace of interconnection technology development. If incentives to increase distributed generation are in place, it will create interconnection problems.
- Utah must legislatively remove regulatory barriers—streamline the process of permitting and siting of distributed generators and of verifying interconnection is feasible. The process is too difficult, so many companies do not consider it an option, and lose out on productivity gains from reliability.

Technologies

Renewables

Solar

- Facilitate connections between universities and companies to develop solar energy technology.
- Encourage manufacturing, wholesale, and retail solar industries.
- Market solar energy. For example, sponsor or publicize a state "Solar Parade of Homes."
- Make incentives—by passing an alternative energy tax credit or net metering bill—to make it attractive to businesses and residents to use clean energy

- Help to educate the public on efficient ways to conserve. Attitudes towards conservation will heighten interest in cleaner, more efficient energy production.
- Determine what the barrier is to receiving 50 million in federal funding for a solar-powered cosmic ray testing site in the western Utah desert. Utah state researchers have applied for such a grant and need its approval to be facilitated. The state could help.
- Examine the possibility of developing solar pools with the brine-rich saltwater in the Great Salt Lake.

Wind

- Employ the NREL to perform an up-to-date wind survey with modern technologies. We are certainly not utilizing all capacity available. We must know where we can develop wind capacity.
- "Build it and they will come." If we build some capacity, other companies with interest will be attracted to the area.
- Be involved in the Wind Conference in October and the Industries of the Future Showcase in August.

Hydro

- Contact the Utah State University Water Lab for records on hydroelectric sites, especially potential at Bear Lake.
- Contact the U.S. Department of Energy concerning their findings of hydroelectric potential in the state.

Geothermal

- Encourage growth in geothermal technologies in industry. A new turbine being developed by a Utah scientist offers promise. Facilitate the development of unexploited capacity in Milford.
- Determine capacity of Milford plant and use it.
- Create distributed generation facilities. While large-scale opportunities are being exploited, small generators could be built to supply small campuses or single buildings with power using smaller deposits of water or steam.

Microturbines

- Utah should contact Rolls-Royce to assess the possibility of bringing microturbine design, research, testing, or production to its Utah facility, in order to gain a presence in the industry.
- See distributed generation recommendations.
- Utah has a presence in aviation technology. Since microturbine technology evolved from jet engines, and many jet engine companies have microturbine producing businesses, we may be able to encourage such companies with aviation contacts to come to Utah.

- Most of the economic activity in microturbines is happening in the industrial area. While engineering and design are important to the industry, it is a highly industrial sector. The state should exercise caution in bringing microturbine manufacturers to Utah, since they will not provide high-tech jobs, but manufacturing jobs.

Fuel Cells

- Olympic Technology Expo – The Olympics will be a great opportunity to showcase Utah's technologies to the world. By hosting a Utah Technology Expo, little known and ignored companies could have the opportunity to gain some exposure and possibly make contacts with the various business leaders from around the world that will be attending the Games.

- Application-Specific Fuel Cell Development – Encourage Utah companies to develop application-specific, market-ready products by contracting with these companies to develop efficient energy applications for small state infrastructure projects (lights, road signs, etc.) Fuel cells are perfect for remote areas far from the electric power grid. This is an opportunity for rural, isolated areas to generate the power necessary for things like Smart Sites and other energy-intensive facilities. By challenging the companies to develop market-ready products, the State can simultaneously encourage the companies to adopt a market focus, while at the same time solving some of its own energy concerns.

- Focus Funds in Hydrogen Research – The State needs to be very strategic in its appropriation of funds for research. Efficient production and storage of hydrogen continues to be the greatest hindrance to the commercialization of fuel cells. Currently, the most efficient (yet relatively inefficient) process for obtaining hydrogen is the reformation of methane. Methane can be produced from coal, of which Utah has a large amount.

- No company, state, or nation has yet to become the leader in hydrogen development. The potential growth and economic benefits to the region that develops hydrogen efficiently will, by comparison, far exceed that of the OPEC nations.

- Make Utah a Test Site for Fuel Cell Vehicles – The State and its universities already have some ties to the auto industry. Utah needs to leverage these relationships to encourage the mass testing of fuel cell commercial passenger vehicles in the State. For instance, Utah has the famous Bonneville Salt Flats that could be used for a Fuel Cell speed record contest between fuel cell car developers.

- Convert All State Fleets to Fuel Cells – The quickest way to gain the attention of the fuel cell industry is to become one of its largest customers. As has been pointed out, costs can only come down if there is more production, and there cannot be production without demand. The example of SunLine Transit in California shows that such a bold move has the potential to make an organization a leader overnight. If UDOT converted all of its fleet to fuel cells, Utah would instantly attract the attention of the whole industry. The State can then partner with other companies to develop the hydrogen production/refueling infrastructure to make Utah the first region in the world where the general public drives vehicles powered by fuel cells.

- Alternative Fuel Policy – Just as California has created excitement in the industry, and demand in the market, with its policy to have ten percent of California cars be zero-emissions in 2003, Utah could facilitate commercialization of fuel cells by making similar requirements. By talking about it and advocating it, Utah can become a major center for fuel cell development - something that will be attractive to many companies seeking to produce fuel cells en masse in five to ten years.

Superconductors

- The State should encourage PacifiCorp/UPL to launch a superconductor project in Utah.
- The State could initiate a government project like `the Detroit HTS Cable Project`. Such a project would bring superconductor experts and companies to Utah.
- Second, the State could target superconductor companies by using grants, contracts, and tax incentives, and by promoting Utah's favorable qualities. Bringing superconductors companies here would be a good start to building a superconductor industry presence.
- Utah could help to initiate superconductor and cryogenics research projects at its universities. There are only a few professors in Utah's university's that are researching superconductors and cryogenics. The State could provide funds to subsidize the salaries of top superconductor and cryogenics researchers in order to attract them to Utah. Once there is a significant group of these researchers this could be used as a selling point to attract superconductor companies.

Introduction

A Context for Discussion of Alternative Energy in Utah

"My impression is that Utah may be best suited to contribute in niche areas or on subsystems, but may not want to commit the resources that would be required to become a major contributor [to alternative energy]. None of these technologies is now economically competitive with traditional power generation technologies, but some are within a factor of 2 to 3 of being so and there are relatively clear development paths that will close this gap."

Larry Baxter
Director, enter for Combustion Research and Engineering Technology
Brigham Young University

Energy is big news lately. Whether it is the California rolling blackouts, the Nation Energy Policy, new power plant construction, electricity price caps, gas price hikes, or power crunches in places as far away as Brazil or Southeast Asia, everyone from Washington politicos to western CEO's wants to own a piece of the energy issue. And exactly who ends up "owning" energy will dictate the future of energy policy.

*"To achieve a 20th Century quality of life—enhanced by reliable energy and a clean environment—we must **modernize our conservation, modernize our infrastructure, increase our energy supplies, including renewables,** accelerate the protection and improvement of our environment, and **increase our energy security**."*
--Vice President Dick Cheney

This section will outline the dynamics of the energy issue, as context for a discussion of the alternative energy industry and the contribution it might make to Utah's future as a high-tech center. Later sections of this report will highlight the urgency with which Utah must act towards energy policy and energy providers, as well as with respect to developing energy technologies. Much of that urgency comes from the market forces alive for a limited time in each segment of the alternative energy industry. But this section will address the specific political and economic developments that make it imperative that Utah act quickly to secure a place in the future of energy development and technology.

We offer here a context for a discussion of energy policy and the alternative energy industry by analyzing some of the trends and events that have made energy one of the most salient issues politically and economically. The analysis begins with the current national energy situation with a brief argument for deregulation, with particular focus on California's energy crisis and what Utah can learn from California's energy woes. Other national trends such as consolidation of traditional power, construction of new power plants (especially gas plants), and environmental issues will be discussed. Then, we address Utah's energy readiness and resources. This section concludes with recommendations on policies Utah lawmakers might address to keep Utah energy plentiful, clean, and cutting-edge.

National Energy Situation

High gasoline prices, and the rising prices for natural gas and electricity are perhaps the most visible effects of the current energy "crisis." There is truth in the conservationists' complaint that the consumer economy has no mechanism for regulating our consumption of energy. Further, without a collective effort on the part of energy consumers to conserve energy, we will not only cause harm to the environment in general and to certain ecosystems in particular, but will find ourselves in short supply of energy resources or will be forced to take energy inputs (coal, gas, oil, etc.) from the earth in ways that are increasingly costly and harmful.

That said, it is not at all clear that the U.S. is consuming energy without regard to the future of the environment or to the future needs of other consumers. While it is true that even as the U.S. represents 4.5 percent of the world's population we consume 25 percent of the world's power, we also must temper the rush to judge our consumer-driven economy with the fact that the U.S. produces about 28 percent of global output (Reed Wasden Research 2001, 5). From this, it becomes clearer that the U.S. economy is very efficient in its use of energy.

In fact, according to Reed Wasden Research, between 1973 and 2000, the amount of energy required to produce a dollar of output decreased by 42 percent (2001, 5). Increased efficiency has allowed the U.S. to grow production, increasing the gross domestic product by over 66 percent since 1980 (U.S. Bureau of the Census 2000). For such a large production increase, total energy consumption has increased only about 26 percent (Reed Wasden Research 2001, 5).

"A fundamental imbalance between supply and demand defines our nation's energy policy . . . [it] will inevitably undermine our economy, our standard of living, and our national security."
--National Energy Policy Commission

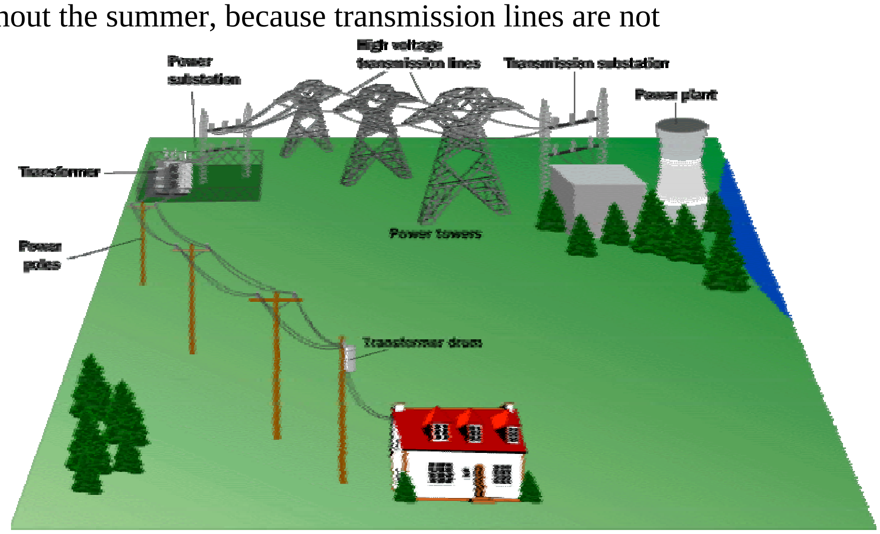
However, in terms of efficiency, the U.S. lags behind other major producer nations. The U.S. energy input per dollar of production is twice as large as Japan and Germany. While the energy we use may be reflective of different types of industries with different levels of energy intensiveness across different nations (the U.S. may have more energy-intensive industry as a percentage of our national economy), it is clear we must improve efficiencies.

Increases in efficiency and the resulting increases in production have actually enabled further growth and led to increased demand for power. However, because power producers (until recently with deregulatory legislation enacted in Congress and at the state level) lacked incentives to invest in new generation capacity and over-invested in their old power plants, new generation capacity has not been built, and the U.S. largely relies on a 1950s-vintage power production and transmission system to supply its energy needs.

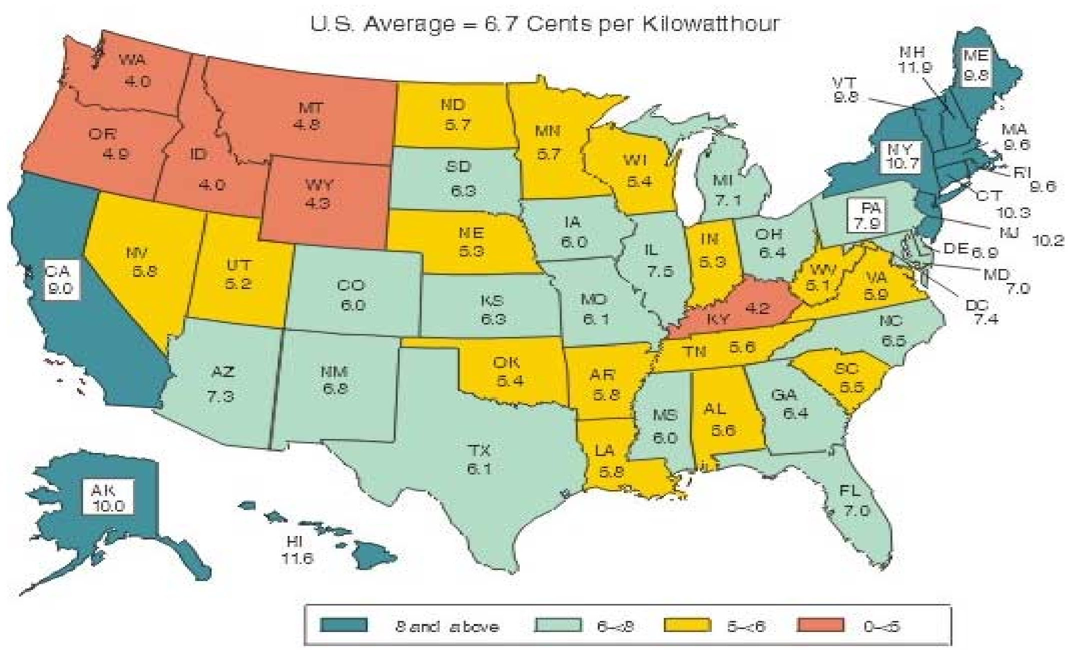
Incentives for construction of power generation capacity were reduced by the lengthy and costly siting, permitting, and approval process for new power plants. Based mainly in concerns for the environment and the fear of having "stranded" (unused) power, permitting regulations effectively prevented the construction of new power plants for the last 20 years. The effect is that economic growth, especially in the high technology sector, which is much more energy intensive than traditional industry, has caused a power glut that has left many areas of the country with excess demand for power.

The National Energy Policy Commission writes, "A fundamental imbalance between supply and demand defines our nation's energy policy. . . . This imbalance . . . will inevitably undermine our economy, our standard of living, and our national security," (National Energy Policy Commission 2001, viii). At the rates of increase of the past decade, energy demand will outstrip supply by about 55 quadrillion Btu (2001, viii).

Further complicating the issue is that the U.S. lacks a national electricity distribution grid. While there are currently excesses of power in the Northeast, that power cannot be efficiently transferred to the Northwest for use by those who are primed to experience shortages throughout the summer, because transmission lines are not integrated across the whole nation. In 1935, Congress enacted a law intended to prevent holding companies from gaining interstate monopolies in power production and to discourage the companies from gaining market power (ability to affect prices in the electricity market). The unintended effect of the legislation, called the Public Utility Holding Company Act, has been to decrease incentives to maintain interstate grids. The result: Texas can export power to California, but not to Arkansas. California can receive power from Mexico, but not from states close by.



The lack of an effective national transmission grid (see picture to the right for a diagram of how the power grid works; taken from “Power Grids,” www.HowStuffWorks.com) contributes to the market’s being “spotty.” Prices vary widely from state to state, because electricity from one state cannot be effectively shared with other states. States with surpluses cannot always transmit power to states with shortages. The result is that the U.S. electricity market is a non-existent entity—we have 50 separate markets, each with their own price equilibrium, rather than a national equilibrium price. The price variation from state to state is shown in the map below (Energy Information Administration 2000).



Legislation

However, with 1997 legislation intended to spur the deregulation of the electricity industry, incentives are changing nationwide. The 1935 Act had been well intentioned. At the time of its passage, half of all power generated in the U.S. was under the control of three large holding companies that sold power services at excessive prices, drove up the prices of power generation plants, and were even accused of “stock watering and capital inflation, manipulation of subsidies [to enhance revenues],” and other illegalities described in the Sherman Anti-Trust Act (Energy Information Administration 2000). The Act required the holding companies to divest themselves of their assets until they could be deemed “a single consolidated system serving a circumscribed geographic area,” (2000). Interstate lines were prohibited unless they could be proven necessary. And in order to discourage the new development of holding companies, which sold power wholesale after purchasing it from the generation companies, which the holding companies often owned, the Act prohibited the selling of power by any entity other than a "singly, integrated utility," (2000). This initiated the rise of power generation utilities as the sole wholesalers of power.

To offset the trend towards a non-integrated grid, Congress passed the Public Utilities Regulatory Policies Act (PURPA) in 1978. It required grid connection between utilities. Also, the Act allowed small, non-integrated generation firms to produce power, and forced the utilities to purchase power from these "Qualifying Facilities" (QFs). QFs are non-integrated facilities (meaning they were non-utilities) that provide power efficiently and cleanly, either by using cogeneration (generation of heat and electricity, or of heat for the further production of electricity by using the heat to boil water and turn steam turbines) or by using renewable resources for energy production. The utilities are required under PURPA to purchase all the power produced by QFs, in order to encourage more firms to engage in efficient and renewable resource production.

> ***If consumption continues at current rates, American oil deposits will yield about 70 years worth of oil.***
> --American Petroleum Institute

In 1992, PURPA exemptions were expanded beyond QFs, to include "exempt wholesale generators." The new exemptions, part of the Energy Policy Act of 1992, allowed utility and non-utility plants to have government-created markets if they would build non-rate-based power plants. In doing so, the Congress guaranteed that the power produced in such plants would be transmittable to public utilities, as under PURPA, but did not guarantee that their power would be produced. The Act removed the incentive to over-invest in existing capacity, by providing an incentive to break away from the old return-on-investment system and take their chances with a return-on-service system. Under the old system, the electric utilities industry received a guaranteed rate of return on its costs. This stimulated investment in new service vehicles, employee pay increases, office redecoration, input stockpiling, and other over-investment behavior. The 1992 Act allowed a new class of power producers to receive a return not on their production, rather than on their costs, and instead of guaranteeing the rate of return, simply guaranteed the firms would have a market for their power and a way of transmitting it to market. Incentives were to invest in new and expanded transmission infrastructure (grid lines) and to build new generation capacity—all costs of service rather than costs of maintenance.

While an intended effect of the Act was that a national grid system would be created, the technical feasibility of such a grid is currently under investigation by the President's Commission on Energy Policy. Transmission between utilities and between geographic areas (read: states) has improved, but the market remains "spotty," meaning that there is still wide variation in wholesale prices due to geographic distance. No price equilibrium is reached because the transmission of power is not really a fluid, efficient process.

The Energy Policy Act signaled to the states that the federal government no longer considered power production to be a natural monopoly. While it is true that the

Act did nothing to deregulate the industry, it did realign the incentives for production of new electrical generation capacity and new transmission lines, and therefore, provided a context for the states to adopt deregulatory and industry restructuring measures of their own.

Oil and Natural Gas

Electricity is not the only energy with which we concern ourselves. The nation currently faces an emerging oil and natural gas shortage, as highlighted by the National Energy Policy report released by Vice President Cheney in May of this year. The Policy warns that U.S. transportation and production are too reliant on foreign sources of oil, and recommends new drilling, as well as the construction of a natural gas pipeline.

As the report reveals, even at current rates of growth, which are conservative in the face of growth projections for the next 20 years, U.S. demand for oil will be increasing by about 6 million barrels per day. Supply, if it follows current supply trends, will actually decrease by about 1.5 million barrels per day, leaving us with a shortfall in 2020 of about 19 million barrels per day (National Energy Policy Commission 2001, viii). Further, if consumption continues at current rates, the American Petroleum Institute projects that American oil deposits will yield about another 70 years worth of oil (200 billion barrels) (2001). Total world reserves total about 2.3 trillion barrels (2001).

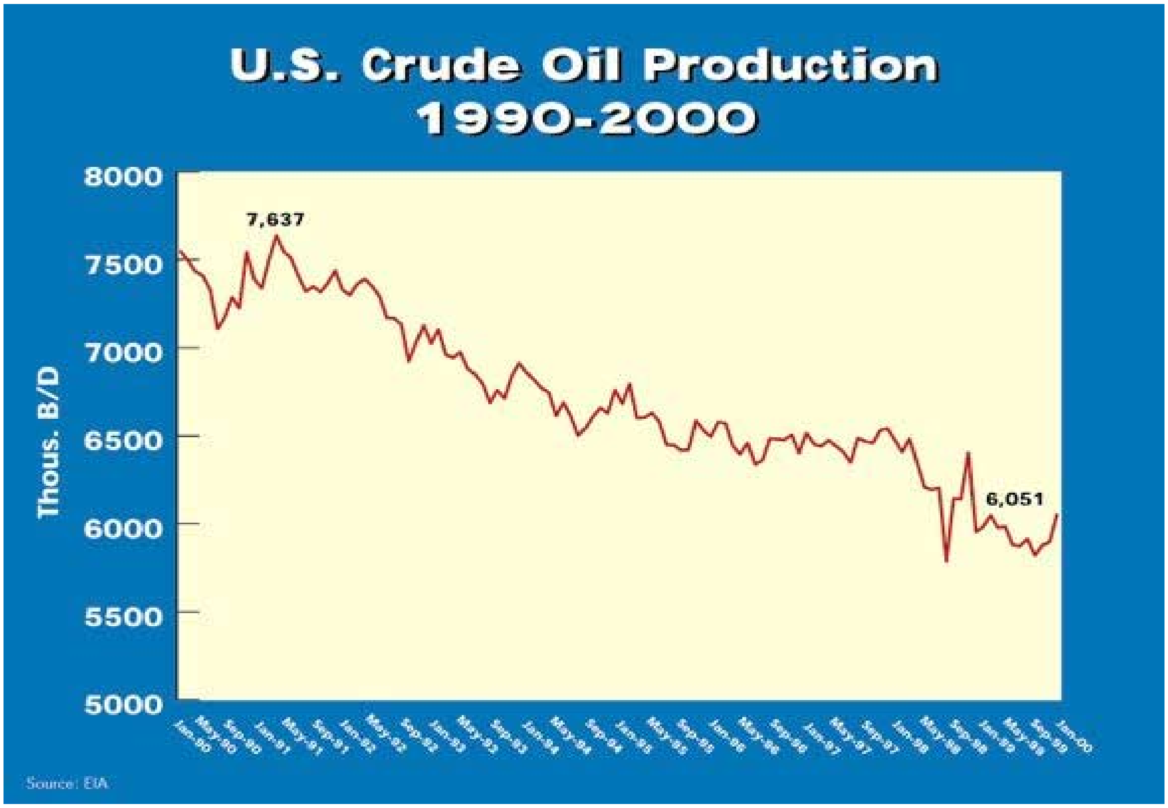
> ***"We live in a fossil fuel world."***
> --Utah energy researcher

For natural gas, the picture is not quite so bleak. But, it is still depressing that while demand for natural gas will grow by over 50 percent over the next 20 years, supply, at current production rates, will only grow by 14 percent.

The projections in the report assume that "we live in a fossil fuel world," (Smoot 2001), and that there is little possibility of that changing in the next 20 years. Promising technologies increasingly rely on natural gas to produce electricity or to move vehicles or to fire turbines. If natural gas becomes the coin of the energy realm, oil productions may be happily over-projected. However, the projections for natural gas may be woefully underestimated. As was hinted in the Utah Energy Technology Summit this past May, at current rates of consumption, there may be between 40 and 100 years worth of natural gas left in known and speculated reserves. Therefore, moving towards an economy that is increasingly dependent on natural gas does not solve the long-term fuel supply problem.

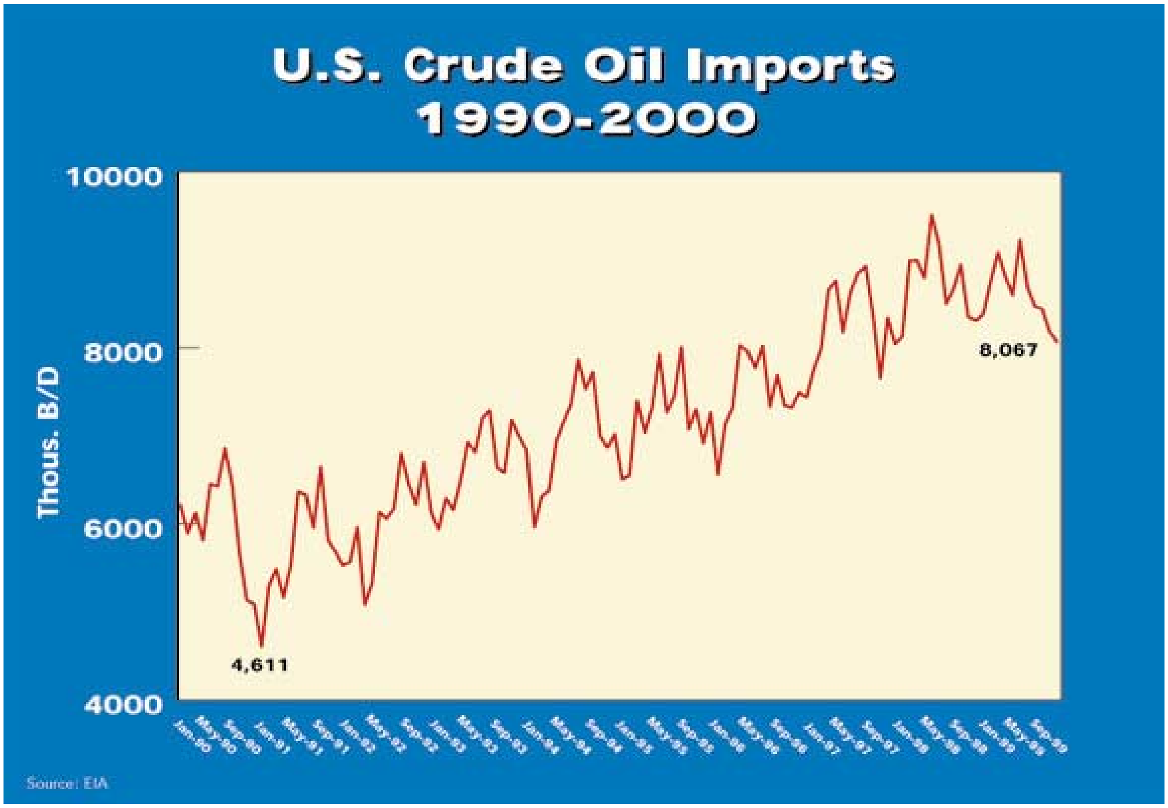
Clearly, neither oil- nor natural gas-based energy solutions can guarantee sustainable growth after 2100. Our access to world oil reserves through foreign trade offers an option, but the costs (risks) of dependence on foreign oil are high.

Oil imports make up about 56 percent of total oil consumption in the U.S., (Energy Information Administration 2000), and by the year 2020, U.S. oil production will only be able to supply 30 percent of our national demand. The gap is widening. Since 1992, domestic oil production is down 17 percent, while domestic consumption is up 14 percent. Since production and consumption are moving in opposite directions, and at different rates, there is no way to avoid importation of oil.



However, importing oil has created economic dependency on oil-producing nations. Senator Murkowski, citing the Energy Information Administration, estimates that Americans spend about $300 million per day on imported oil, for a yearly total of over $100 billion.

The graph below (Energy Information Administration 2000) shows the growth in U.S. oil imports since 1990. The trend line shows that imports are growing, increasing our dependence on sources of foreign energy inputs.

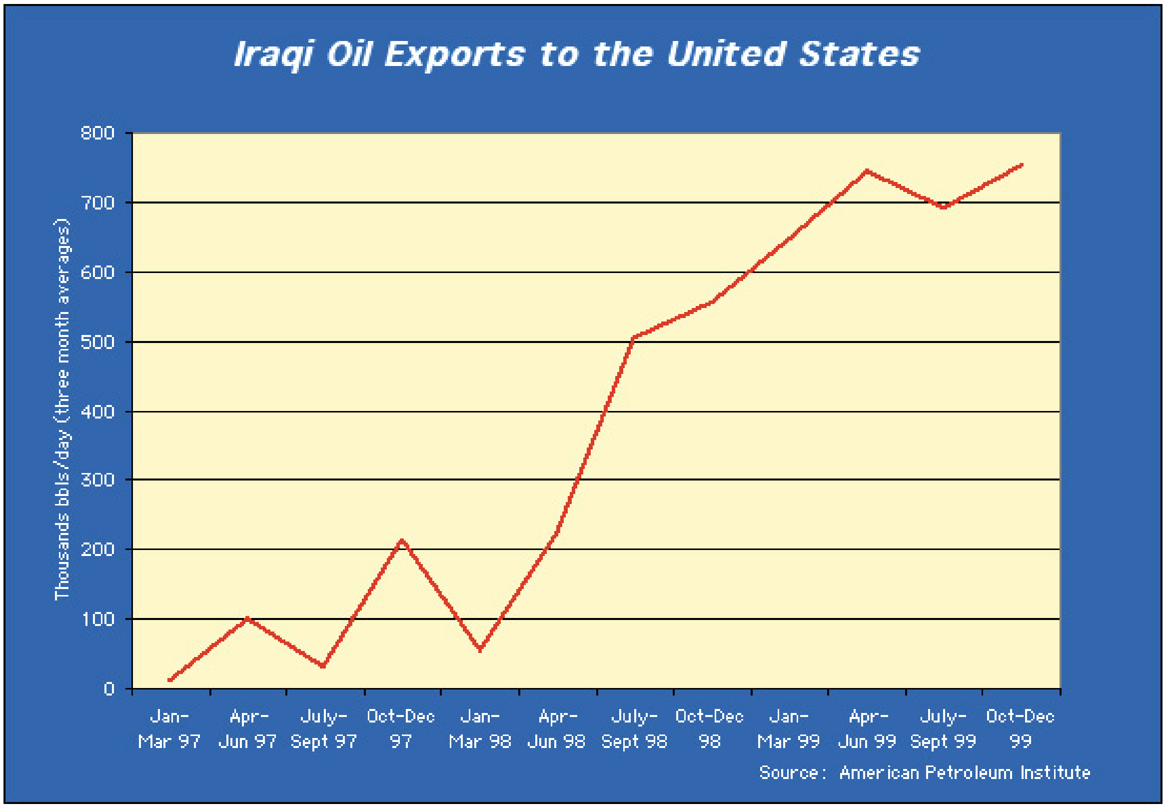


Totten and Settina, researchers at the Center for Renewable Energy and Sustainable Technology, report that the U.S. currently spends about $50 billion per year on foreign oil. “Without a concerted effort to improve the efficiency of vehicles and our transport system, and to adopt alternative fuels . . . [we predict] a massive increase in foreign oil imports. At an annual oil consumption growth in the U.S. of one percent per year, all conventional U.S. oil resources will be depleted by 2009,” (2001).

> ***“Two-thirds of the world’s remaining easily accessible oil deposits are located in the volatile Middle East, the threat of sudden price shocks and embargoes will remain a fundamental problem”***
> --Totten & Settina, 2001

It becomes clear that energy is not only an economic issue, but a national security issue as well. As such, security of our energy supply depends on the stability of our providers, as well as on the stability of our relationships with them, and on the usage of other countries.

Totten and Settina write that, “Two-thirds of the world’s remaining easily accessible oil deposits are located in the volatile Middle East, the threat of sudden price shocks and embargoes will remain a fundamental problem,” (2001). The stability of our oil trade relationships depends to heavily on local politics for it to be safely “assumed” the way that our projections assume the existence of oil supply (see graph below).



Also, as national economies modernize in what are currently developing countries, competition for oil supply may drive up world oil prices, and further limit the number of years the U.S. can sustain its consumption of oil.

Oil is not a regulated industry, in that no government-protected oil monopolies exist. However, within the world oil industry, the symptoms of monopoly economics are alive, because of observed oligopoly behavior in American firms (price increases despite increasing supplies), government ownership of foreign oil producers, and foreign oil cartels like OPEC.

> ***At current consumption levels, the U.S. oil supply will be depleted by the year 2009.***
> --Totten & Settina, 2001

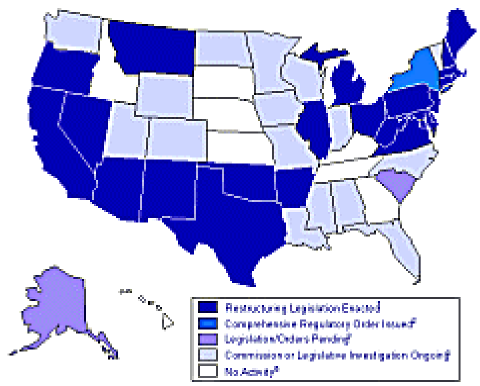
The natural gas industry, like electricity, was a regulated industry, but has now undergone three phases of deregulation. First, the Natural Gas Policy Act of 1978 phased out natural gas wellhead regulation, which was completed by 1993.

The second phase was accomplished entirely at the executive level. The Federal Energy Regulatory Commission (FERC) issued order 380, eliminating the variable cost component of local gas distribution companies' (LDCs) minimum bill requirements. In so doing, Congress provided LDCs the incentive to switch gas suppliers (Costello & Duann 1996). FERC Order 436 allowed open pipeline access, in return for certificates from participating distributors that they would transport third party gas. Order 436 stimulated the growth of third party gas wholesalers (1996).

The final phase came as FERC Order 636 in 1992, which prohibited pipelines from offering bundled distribution services, and gave transport customers nondiscriminatory access to the pipelines. This stimulated market development down to the pipeline-user level.

Deregulation

Deregulation has not taken place on a national scale in the electrical generation, transmission, and distribution. Several states have attempted to partially deregulate the electricity production and wholesale industries, while many other states are considering following their lead. As of July of 2000, comprehensive deregulatory orders had been issued in only one state (New York) and 22 states had passed restructuring legislation (Energy Information Administration 2000). The map included shows the development of industry restructuring in the U.S.



Proponents of deregulation or partial restructuring of the electric power industry support it on several grounds. The current system, as previously noted, provides incentives contrary to the public interest. Guaranteed rates of return on investment in existing infrastructure creates a return on assets, the value of which is enhanced by over-investment in superfluous infrastructure—line replacement, needless updates to old power infrastructure, office redecoration, adding new cars and trucks to firms' fleets, increasing numbers of employees. The general idea is to increase the costs of operation, since the rate of return is based on costs.

> ***"Without restructuring, it is impossible to project a return on investments in power plants, so investment in new plants is discouraged."***
> --Utility executive

What does not exist in a regulated system is the incentive to invest in service. Anything that does not increase assets will not receive investments, because there is no guarantee of a return on the investment. For example, power generation companies will not invest in new generation capacity, because it may threaten to replace their current assets, or to create an excess of capacity that gets "stranded." So, ratepayers and investors are loath to pay for reimbursing the utilities' costs of construction. In an interview in connection with the Utah Technology Summit on Alternate Energy, a utility executive said, “Without restructuring, it is impossible to project a return on investments in power plants, so investment in new plants is discouraged.”

Likewise, power generation companies will not invest in emerging technologies, since they threaten to replace their existing capacity with more efficient, cleaner, and eventually more cost-effective and reliable power. In the event that such technology did emerge, the entire assets of the utilities (coal-fired plants, nuclear plants, etc.) would be stranded.

Technological development, though, is endogenously related to the development of deregulation. Not only may deregulation spur growth in the high-tech and alternative energy sector, but technological development spurred deregulation (Energy Information Administration 2000). Cleaner, more fuel-efficient technologies have begun to be cost-effective, making non-traditional power producers a viable force in the power economy (2000). Competition with non-traditional utilities has opened the trend towards greater competition in the electricity generation industry.

However, the stranded costs issue must be resolved or utilities will have no incentive to support industry restructuring. An industry executive referred to stranded costs as the largest barrier to restructuring. “The public thinks they paid for the construction of power plants by paying their electric bill. Until the public understands that their bill only covers cost of service plus capital depreciation, and that investors pay for new power plants, there will always be this disconnect.”

The disconnect to which he refers is rooted in the “who pays” question of new generation capacity. In general, the public believes they paid for power plants currently in use. The producers say that private and public investment paid for the power plants, and that the bills consumers pay have nothing to do with building new capacity.

The disconnect becomes a problem, because in order to restructure, electric monopolies would be required to divest a large percentage of their generation and transmission capacity. The stranded costs in unused capacity and capacity that they paid to build, but on which the producers will not see any return on investment must be paid for.

California and other states chose to include a “transition fee” in utility bills. The proceeds from the fee are intended to cover the stranded costs of power companies. The fees are charged for a limited number of years, until the costs are covered.

> ***“The public thinks they paid for the construction of power plants by paying their electric bill. Until the public understands that their bill only covers cost of service plus capital depreciation, and that investors pay for new power plants, there will always be this disconnect.”***
> --Utility exeutive

Another flaw in the regulated system is the lack of real price signals. In the presence of price caps and regulated retail rates, purchasers of wholesale electricity do not see the costs of the generating firm, and retail customers are even more removed from the price equation.

In sum, partial deregulation or industry restructuring is necessary to spur investment in new generation capacity, which especially in the West is currently lacking. New transmission capacity lacks investment, which would be corrected by restructuring the incentives to invest.

Finally, and most relevant to the alternative energy focus of much of this report, industry restructuring would increase incentives to invest in emerging technologies. Because exposing protected utilities to market forces makes it impossible for them to remain isolated from emerging technological solution to old power problems, economists predict the emergence of hyper-utilities offering a diverse set of power products to satisfy multiple consumers, rather than the strict, centralized grid power product currently offered by most utilities.

Once divested of assets, the expectation of proponents of restructuring is that power generation companies may be slower to pick up market signals related to service and products, because of the equity in their status as the “power company.” Customers will not immediately leave power companies just because the industry is deregulated. Habit and, in most cases, a historically good relationship with the previous monopolist power company will provide a certain level of customer inertia. The result: deregulation will not force companies to immediately innovate.

However, the power companies will eventually begin to be challenged for their customer base by distribution companies and other wholesale and retail providers of power, who will offer a different range of services. To remain viable, former monopolies will “build energy solutions for their residential, commercial, and industrial customers by buying, building, or partnering with the technology providers that can help customers solve their energy problems,” (Reed Wasden Research 2001, 7).

Therefore, we can predict that power companies will not only be influential in funding and partnering for technology research, but they will become some of high-tech power’s biggest customers. For example, because grid power is only 99 percent reliable, and the one percent left over could cost energy intensive industries billions of dollars in lost productivity, power companies faced with competition would begin to offer on-site power generation and back-up generator systems as part of their array of products. For residential power users, they may offer green power, spurred by competition with smaller green producers.

The California Power Crisis

Despite its economic benefits, and being heralded by most analysts as a driving force behind technological innovation, “deregulation” has lost political favor because of its perceived failure in California. Public scrutiny of the California power crisis has led many to believe that deregulation proposals could never work in Utah, noted a Utah utility executive. However, California's problem is only relevant to Utah because it provides the basis for learning how not to restructure.

The next few paragraphs will show how California's power crisis came to be, and how it actually creates an opportunity for Utah to succeed, and how Utah can spur both its power production capabilities and its development of energy technology with a deregulation strategy.

Deregulation in California was undertaken amidst political euphoria related to the resurgence of conservative politics in America during the mid-1990s. In that context, deregulation was legislated in a "big bang" approach that saw California undertaking to deregulate its most heavily regulated industry in a one-year time frame. Hence, its first problem: California deregulated too abruptly (World Bank 2001).

Second, the California crisis was years in the making, and to a large extent, deregulation was only a catalyst for an already impending energy supply shortage. The siting and permitting process was highly political, and environmental restrictions on power plant emissions and construction compounded the process of building new capacity (Reed Wasden Research 2001, 2). In fact, in the five years preceding deregulation, California authorized no new power plants (World Bank 2001); and in the ten years before deregulating, environmental, political, and bureaucratic hurdles blocked any significant generation capacity construction (Besant-Jones & Tennenbaum 2001, 5). In fact, between 1997 and 2000, generation capacity in the State of California decreased by about 1200 MW (2001, 4).

In the year 2000, Silcon Valley's energy consumption grew about 12 percent. --Reed Wasden Research

In November of 2000, 13,500 MW of additional base-load capacity was "taken off the market." Some of that power was tied up in old power plants undergoing maintenance. A large portion of those MW of electricity was imports from the Northwest that were no longer available for purchase, due to low water years in the Northwest (World Bank 2001; Besant-Jones & Tennenbaum 2001, 5). In essence, California had exported its energy crisis to other states that could handle the additional generation requirements. But supply shocks in those states made California's reliance on out-of-state power a huge liability for them.

Demand was also increasing all over the state. The demand shock was unexpected—30 percent power reserve margins present in 1994 were expected to last until 2004 (Reed Wasden Research 2001, 2), but the digital economy exploded in the late 1990s, with Silicon Valley's power consumption growing about 12 percent in 2000, while the rest of the state's consumption grew about two to three percent during the same year (2001, 2).

Also, the supply of natural gas for gas-fired plants was (and is) constrained by infrastructural problems, and is much more expensive than coal. Natural gas is usually used to fire peaking capacity plants, garnering more revenue than coal-fired energy because the gas plants are used at peaking hours, when the price per MW-hour is higher. With those plants running full-time, power generation was more expensive, but unable to recoup its costs.

Also, uncertainties with the new market delayed investment in new generation (World Bank 2001). California should have prevented delayed investment by deregulating when it had an excess of power that was stable and in-state. In any deregulation scheme, there will be a period of adjustment. The period of adjustment for California came at exactly the wrong time.

The third failure of California's deregulation is market inertia. "The incumbent power providers have one valuable competitive advantage—their current captive customer base. If nothing else, this customer base perceives them as 'the power company' possessing some expertise in power delivery," (Reed Wasden Research 2001, 7). The customer's resistance to change stems from the lack of change in post-deregulation power bills, due to extra "transition fees." Less than two percent of residential customers changed electricity suppliers (Besant-Jones & Tennenbaum 2001, 5). . Customers, seeing no cost benefit to switching providers, stayed with their power providers, who having divested about 50 percent of their generation and transmission assets, now lacked power to sell to their customer bases, and had to purchase it elsewhere.

The problem was compounded by the fact that the transition fees, intended to recover for the power generation companies their sunk costs of building the plants in the first place, were too large (Reed Wasden Research 2001, 5). Rate payers paying these "stranded costs" paid for many plants that were already obsolete—already fully depreciated, and therefore, not really "assets" let alone stranded assets (2001, 5). According to Reed Wasden Research, about 55 percent of capacity was older than 30 years, and the remaining 45 percent was certainly not all "stranded," as it had depreciated some. When California calculated the ratepayers' burden for the recovery of stranded capital costs, they assumed that one hundred percent of assets were stranded.

> ***"Deregulation only works if you figure out who is going to pay the stranded costs—and the rate payers are the one's who should pay."***
> --Utility Executive

The fourth failure is rooted in the spot markets created by Cal PX, the major electricity exchange. Cal PX allowed power to be sold in an auction on a day-before and day-of basis. Long-term contracts were forbidden. The lack of forward contracts and long-term contracts allowed the spot prices to fluctuate wildly, mostly in the positive direction.

As wholesale prices increased, retail prices were capped and set by FERC and the California Regulatory Commission (CRC), respectively. Therefore, although prices for power were rising daily, the power companies' ability to recover their costs of generation (or purchase) was limited by the retail prices set by the commissions. In fact, as of

March 2001, the two largest utilities had "incurred about $12 billion in unfounded liabilities," (Besant-Jones & Tennenbaum 2001, 7). Therefore, the retail market did not respond to prices, because the retail price was artificial. As a result, PG & E, California's largest power provider, has declared bankruptcy.

The fifth failure of California's deregulatory effort was not requiring local utilities to deregulate. In general, the local utilities, given the choice, chose to remain public (2001, 6).

The last failure addressed here is that because spot markets were poorly designed. Providers purchasing power on the market were not able to manage their risks and liabilities (2001, 6). Faced with an increasing demand for power, the companies had no choice but to accept spot prices on credit, and in so doing, incurred debts they were unable to pay. As a result, provider credit ratings have suffered, and they are unable to purchase power, as fewer and fewer financial institutions will fund their purchase needs. The State of California had proposed to purchase power in behalf of the companies, taking advantage of their good credit rating. However, the state's rating has suffered in the past month, and fewer creditors will lend to the state.

A better market would require long-term power contracts, which would manage the volatility of the market under unsure circumstances (Reed Wasden Research 2001, 3). Also, as suggested by Reed Wasden Research, separation of the three activities of power companies, namely generation, transmission, and distribution should be separate activities carried out by different firms (2001, 3).

Also, divesting themselves of generation assets was insufficient—power companies were left with exclusive control over access to the grid, and the grid is the key to power sales (2001, 4). Control and coordination of electricity dispatch needs to be centralized. If the State of California had retained the grid lines, it could have guaranteed open access to the lines.

Unfortunately, the public only sees increasing rates instead of the real problems with the design of the regulatory system, and the real costs of power generation in the State of California. Therefore, consumers have been turned-off to deregulation for the time being.

Many have come to see California's deregulatory problems as an opportunity for Utah. Being a state where the "lights are always on" carries with it a certain appeal. And certainly, when making decisions about business location or expansion, Silicon Valley firms will consider power bills and power reliability as factors in their move. However, it does not appear that the power crisis is a primary factor in making businesses relocate, at least not yet. Early evidence shows that Silicon Valley firms are not responding to the power crisis by moving their businesses. Rather, they are looking at other risk management and backup options, like distributed generation, that will provide reliable electricity and make them less dependent on the grid (Patton 2001).

Deregulation and Alternative Energy

However, if alternative energy technology is to develop, deregulation is necessary. Industry restructuring would release the integrated utilities' strangle hold on power supply and open the market to alternative generation capacity, as well as spur research and acquisition of alternative energy technologies. Left to themselves, or rather, given monopoly protection, power companies will not make the necessary investments in energy technology to move it forward.

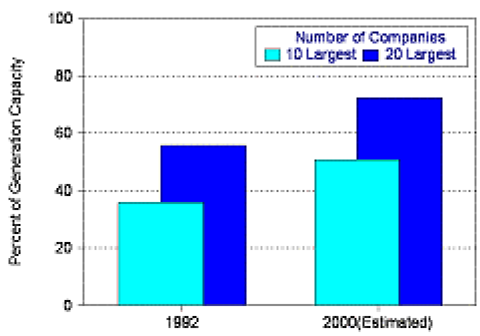
Also, because traditional power companies control the grid, exit fees for users of alternative power systems currently disincent the use of new technologies, who end up paying both for the construction and operation of their own power system, as well as a payment to their power company for backup costs or exit fees.

However strong the case against deregulation in the wake of California's mishandling of its own deregulation, the effects of deregulation in 23 states and the deregulatory spirit alive in American politics still influence the behavior of the electricity industry. Reacting to ever-increasing competition with non-utility generators, traditional utilities have begun merging and acquiring smaller utilities and non-utilities. Merger with or acquisition of a smaller utility or a non-utility is a strategy for increasing generating capacity and service area (Energy Information Administration 2000).

Mergers and Acquisitions

Some mergers have begun occurring for a completely different reason—to diversify products and services. Mergers between electric utilities and gas companies have become common. The rise of national or regional super-utilities has been a defining characteristic of the industry over the last five years (2000).

The result of mergers and acquisitions is that utilities are much larger than they were just 10 years ago. Utah's own power monopoly was acquired first by Pacificorp, which was then purchased by Scottish Power, making Utah Power and Light part of an international power conglomerate. The graph to the right shows the changes in capacity of the largest utilities over the 1990s.



To most utility executives, larger means better. Economies of scale are achieved by "combining resources and eliminating redundant or overlapping activities, [from which] larger companies hope to benefit from increased efficiencies in procurement, production, marketing, administration, and other functional areas that smaller companies may not be able to achieve," (Energy Information Administration 2000). The argument for super-utilities is that it lowers costs, which will lower the price charged to ratepayers.

However, only about 15 percent of electric utility mergers actually achieve their financial objectives (2000). Plans to integrate the merged companies are often underdeveloped, and the lack of competency in new areas often lead to the failure of mergers to achieve economies of scale.

The super-utility relates to the hyper-utility in that many times, it reflects the same corporate strategy. Both strategies are based on "Building on core competencies, securing more customers, consolidating transmission and distribution facilities, diversifying power generating capability, and acquiring additional managerial and technical expertise," (2000). The trend toward mergers should continue, then, as new technologies become viable. "Power companies" will become not only producers of grid power, but also power marketers, power brokers, vendors of distributed power technology, gas providers, telecommunications providers, and so forth.

As utilities grow, so do concerns that oversized utilities will actually do more harm than good. Large traditional power producers emit tons of particulate matter and gas emissions into the air. Environmental concerns and public health issues have come to the forefront of the energy question.

Environmentalism

Environmental politics and regulation have been cited here as a hindrance to development of new traditional generation capacity, halting the permitting and siting of power plants for 10 years in California. However, researchers have noted that environmentalism is a boon to the alternative energy industry, actually fueling innovation and development.

> ***"To most utility executives, larger means better."***
> --Energy Information Admin.

A nationally recognized researcher in alternative fuels noted in an interview with the authors that, "Because of the Kyoto accords and other environmental laws, together with environmental politics, institutions and the federal government have dedicated significant research resources to Biomass as a strategy of meeting the requirements of the Kyoto accords."

Other environmental laws are fueling innovation in power generation. California law (California Health and Safety Code Section 44001 Section C) requiring that by the year 2003, ten percent of new automobiles sold in the state be zero-emissions vehicles has spurred the development of fuel cells in California.

The combustion researcher cited above continues, "[Alternate energy] is not cost-competitive with fossil fuels as a means of producing electricity. However, a sort of artificial market has developed because of tougher environmental regulations in California for new power sources that are cleaner, so comparative cost is not such a huge factor." Federal and state agencies have a legitimate role in protecting the natural environment, and a legitimate responsibility to protect public health. In that sense, the markets for alternative energies created and driven by environmental law are not "artificial" at all. They simply represent a new way of viewing our power production choices. If we eliminate cheaper fossil fuels like coal from the realm of possibilities for electricity production, markets will develop around the next most cost-efficient production input. Environmental policy, then, may drive up the price of electricity, but will also protect public health, water supplies, air quality, and a host of other environmental values.

Two sides :

"Utah is environmentally backward." --Utah researcher

"Utah is not independent of the energy-backward United States." --Utah executive

A Brigham Young University combustion researcher recommended that tougher environmental restrictions are an option for driving development and research in high-tech power. "First, and most effective, would be more stringent environmental regulatory standards. Without standards, companies do not have any incentive to pursue these more costly sources of energy."

"Without [environmental] standards, companies do not have any incentive to pursue these more costly sources of energy."
--Utah researcher

However, we claim that the regulations should be portfolio requirements, rather than traditional regulatory requirements. A recent executive order by President Bush to regulate air quality in national parks with a per-plant output requirement does not contain the proper incentives to continually innovate. By requiring the retrofitting of plants with particular technologies, such policies give companies no incentive to find cheaper, better ways of reducing emissions in order to be able to increase output.

Portfolio regulations, focused on emissions amounts, but relying on companies to come up with their own emissions reduction plans provide incentives to companies to continually make their emissions reduction implementation cheaper and more effective, so that the companies can increase production and still be within emissions requirements.

Environmentally, the State of Utah has two reputations, depending on whom you talk to. Researchers we interviewed regarding alternative energy almost without variation supported the view that, "Utah is environmentally backward, and we are known for being rather slow in implementing environmental regulations. Air quality on the Wasatch front is very poor during the inversion. We do not have a good environmental reputation." Indeed, the data do show that Utah's utilities do pollute significantly:

Emissions	Utah		California
Carbon Dioxide pounds per MWh	20911.37		803
Sulfur Dioxide pounds per MWh	18.42		0.57
Nitrogen Oxide pounds per MWh	43.1		0.63

Utah utilities emit 39,122,874 tons of carbon dioxide into the air per year (20,991.37 pounds per MWh generated), according to the U.S. Environmental Protection Agency (EPA). Also, sulfur dioxide emissions are at about 35,000 tons per year (18.42 pounds per MWh generated), while utilities emit about 80,000 tons of nitrogen oxide per year (43.1 pounds per MWh generated).

For comparison, the State of California, whose population is many times greater than Utah's, only generates about six million more tons of carbon dioxide per year than Utah. And California power producers are efficient, too—only 803 pounds of carbon dioxide are emitted into the air per MWh produced, as opposed to Utah's 21,000 pounds (California is over 20 times more efficient in terms of pollution produced per MWh generated). Of sulfur dioxide and nitrogen oxide, California only generates .57 and .63 pounds per MWh generated, respectively. Per MWh of power production, California power plants are much cleaner. In absolute terms, they are slightly more polluting, but considering the vastness of California's population, Utah is has much dirtier power production than California, no matter how you look at it (EPA 1998).

In order to encourage the development of a high-technology alternative energy sector, the state must evaluate the costs and benefits of tougher environmental laws as a market-driver. Reed Wasden Research notes the empirical effectiveness of environmental law in encouraging market development: "The world's industrialized countries are insisting on creating a cleaner global environment, through initiatives such as the Kyoto Protocol as well as national anti-pollution programs. All of these forces will expand the market for zero-emissions power solutions," (2001, 3).

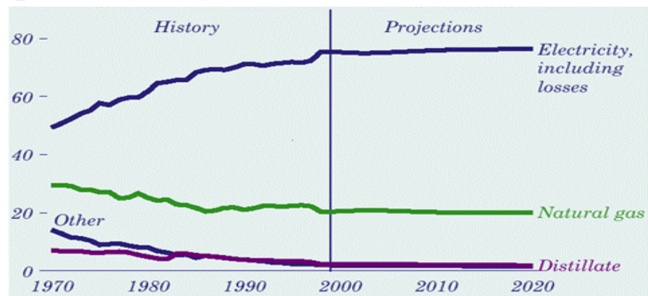
To the degree that environmental laws are legitimate, they act not to distort the market or create artificial markets. They act to correct market failure (externalities associated with production of "dirty" energy). Therefore, instead of making specific regulatory requirements of power producers, state standards should make portfolio requirements, setting a standard for emissions or a specific amount of reduction expected, and allow the companies to determine how they will meet that standard. Innovations, increases in efficiency, and business improvements will naturally develop as companies try to meet new emissions standards without being told exactly "how." Portfolio standards are the least market-distorting types of regulations.

To the degree that environmental laws are legitimate, they act not to distort the market or create artificial markets. They act to correct market failure.

Our other environmental reputation, however, recognizes the important realities in our state's economy. An electric utility executive states that "Utah is not independent of the generation problems of other western states, as well as the problems of the 'backward' United States." The U.S., he says, has been naïve in its development of energy resources, and those countries who are willing to make tough decisions on the use of coal and the construction of large power plants will be those who can infrastructurally handle both population and industry growth. If the U.S. refuses to recognize its need for fossil fuel power production, it will lose out on potential growth.

The Energy Information Administration projects that the use of electricity will only increase, while the use of natural gas as a primary fuel will decrease. That means that coal-fired electricity generating plants will be a growing and important part of our economy in the foreseeable future.

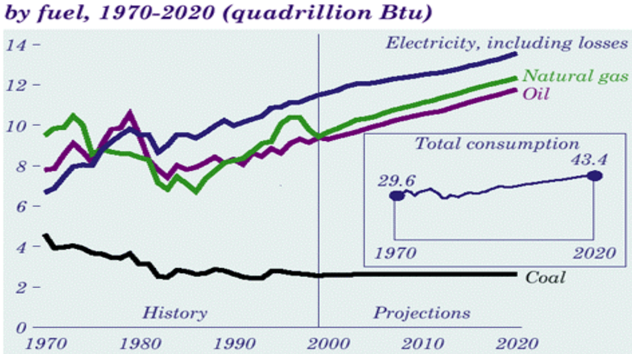
Figure 54. Commercial nonrenewable primary energy consumption by fuel, 1970-2020 (percent of total)



History: Energy Information Administration, *State Energy Data Report 1997*, DOE/EIA-0214(97) (Washington, DC, September 1999), and preliminary 1998 and 1999 data. **Projections:** Table A2.

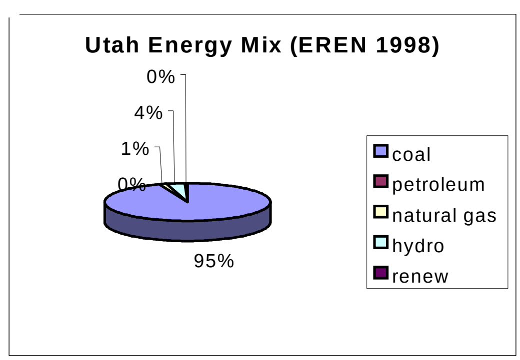
The graphs to the right and below depict the consumption projections for various types of energy through the year 2020 for commercial and industrial users. Note that, especially for industrial users, natural gas and oil figure prominently in industrial energy consumption, but not as prominently as electricity.

Figure 56. Industrial primary energy consumption by fuel, 1970-2020 (quadrillion Btu)

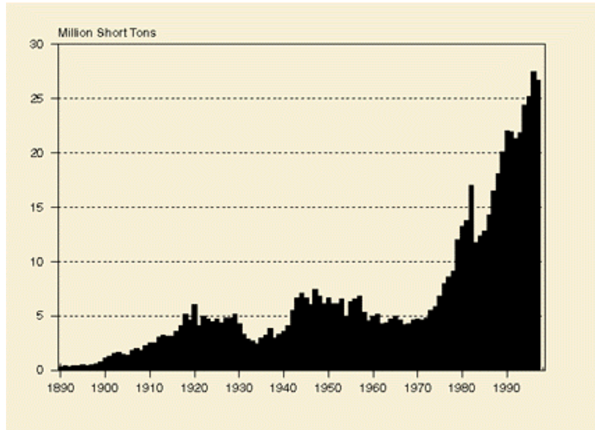


History: Energy Information Administration, *State Energy Data Report 1997*, DOE/EIA- 0214(97) (Washington, DC, September 1999), and preliminary 1998 and 1999 data. **Projections:** Table A2.

Coal, because it is not used in industry, but in electricity production, appears in the graph to be unimportant to future industry. But the graph is deceptive, not taking into account that the steepness of the slope of the electricity consumption line at the year 2020 indicates that electricity use will be increasing rapidly throughout the first half of this century. Since coal-fired plants generate most electricity, the importance of coal to our national and state energy futures cannot be overlooked. Indeed, we must realize that fossil fuels are going to be essential to our future economic viability, whatever the fate of alternative energy technology.



The reality, then, is that Utah is the nation's leading producer of clean coal, although it is not one of the largest coal producing states. Utah coal's largest customer is the electrical power generation industry, which consumes about 15 million of our approximately 16 million short tons of coal each year. Eighteen percent of our mineral/mining production per year is coal. Coal represents about $481,605,000.00 in yearly revenues for Utah. Coal mines employ almost 2,000 Utahans in its 12 mines (statistics from National Mining Association Mining Statistics, 1998 Data, www.nma.org).



Coal revenues and mining are increasing in Utah, as well (see graph. Source: Energy Information Administration, http://www.eia.doe.gov/cneaf/coal/statepro/imagemap/ut.htm)

Almost all of Utah's power production comes from coal. The chart above, based on Energy Information Administration statistics shows that about 95 percent of energy used across all sectors in Utah comes from coal (EREN 1998).

And Utah's energy is inexpensive, as well. Rate increases requested by Pacificorp this week (June 2001) will most likely be rejected in part. However, even with an increase, Utah's power bills would remain some of the lowest in the nation. Cheap power provides an attractive incentive to locate business in Utah, especially for the energy-intensive high-tech sector. A chart comparing Utah's rates to the national highs and lows and the national average. Utah's rates are well below the average rates.

	Residential Sector	Commercial Sector	Industrial Sector
State Average Rate	6.8	5.7	3.5
Nation Lowest Rate	5.3	5.2	3.1
Nation Highest Rate	11.5	9.2	8.7
Nation Average Rate	8.4	7.6	4.5

Energy Information Administration, 1998

Further, research in high-tech combustion is a strong suit for Utah's universities. The Center for Advanced Combustion Research at the University of Utah and the Advanced Combustion Engineering Research Center at Brigham Young University are together the most well-respected combustion research resource in the world. Their research on cleaner burning coal, as well as biomass and natural gas combustion, as well as on cleaner boiler design technology gives Utah an innovative edge in the stodgy coal-fired power industry.

Because of these resources and Utah's excellent relationships with its power providers and mining industry, along with our relaxed environmental regulations, Utah has a competitive advantage in coal-fired power production and technology. Further, despite its recent difficulties in risk management, Pacificorp is recognized as being very strong in the area of coal procurement and operations. To ignore this reality when pursuing a high-tech energy sector would be disastrous.

Specifically, Pacificorp, Utah's largest power provider, owns transmission lines in Washington, Oregon, Arizona, Wyoming, California, Idaho, and Utah, and includes a very small portion of Nevada in its service area. The generation capacity along all those lines is where Utah should focus its attention.

We are not independent power users, nor independent producers, nor can we easily produce extra power and export it. Still more unrealistic would be to plan on reclaiming exported power for ourselves when we need it again, in case of a technology sector boom or a population shock. Because Utah is the fastest growing state on Pacificorp's lines, Utah benefits from the power produced in other western states, and our capacity as a group of states is lower than the demand for power. In contrast to Utah political wisdom, there is not a general excess of power production in Utah. The small surplus that we do have occurs only at non-peak hours, and makes up about ten percent of the electricity produced at those hours. It is sold to California utilities.

Utah's two energy goals should be to develop a high-tech alternative energy industry sector, and to produce sufficient power to sustain the growth of other high-technology industry ecosystems. As this report will demonstrate, Utah lacks resources in areas outside combustion research, and as such, will have to make significant, if not overwhelming investments and policy changes in order to encourage market development. Coal technology and cleaner-burning coal, on the other hand, are already here. And Utah knows them well.

While investing resources in alternative energy technologies is a viable and necessary way to plan for Utah's high-tech and economic future, Utah should not forget that other high technologies have a greater presence in the state, and a better chance of success in defining Utah as a high-tech center than does alternative energy. For the sake of those industries—biotech, software, aviation, and other highly energy intensive industries—Utah must have an abundance of reliable, inexpensive, and efficiently distributed power. Reliance on the grid, and reliance on coal-fired power plants to supply energy to the grid will be the realities of the coming years in Utah's energy future.

In forming its energy policy, then, Utah must integrate its approach to energy with its economic development goals, as well as with its goals for environmental quality. Currently, we have found a surprising lack of coordination between Energy Services and Community and Economic Development (DCED). The recent departure of Energy

Services from its shared location with DCED (owing to a change in Utah's executive agency structure), though unrelated to this observation may serve as a symbol for a future of less coordinated policy efforts.

Because Utah's future is found both in high-technology energy solutions and in increasing energy supply, and because those two goals have competing environmental implications, the importance of coordination between agencies intensifies. For the future of alternative energy in Utah, increased environmental regulation is good business. For the future of high technology in Utah, increased environmental regulation may be a liability and the cause of power shortages or business departures. Agency integration as regards energy policy may help to combine the best environmental regulatory practices with the best energy production sensibilities to create an energy future that is both high-tech and abundant.

Segments

Alternative energy is a diverse industry, including everything from power derived from the sun and wind, to production of the most advanced ceramics ever known. Alternative energy has several goals, the first of which is to develop clean power technology. The technologies we will discuss in the following chapters were justified, especially in their infancy, by their ability to keep emissions low and to use methods of fueling our economy that were not so dangerous precious ecosystems and public health.

Many of the technologies we will introduce here aim to increase efficiency. Our current mass-production plants distribute power to the grid that was produced at 25 to 30 percent efficiency, sometimes lower. That means that only 25 percent of the energy present in the coal or the natural gas burned in power plants actually ever turns into useable electricity. To most efficiency researchers, that is an abomination. Many of the alternate energy technologies promise current efficiencies above those of large power plants, and many promise future efficiencies of up to 80 percent. That means less energy will be used for producing energy, and more can be used in producing goods and services.

The technologies are also enabling technologies. While solar and microturbine technologies are actual power generators, some technologies, like superconductors, facilitate the efficient and loss-free distribution of power from one place to another. Superconductors reduce line-loss of electricity (where power literally jumps off the grid) and increase the transmission capacity of gridlines. This eliminates bottlenecking of power—plenty of power, but too many power users to serve, and not enough lines to get them their power.

Some technologies discussed here are aimed at facilitating the development of primary technologies. For example, fuel cells require a hydrogen economy to develop in order to get the greatest use out of fuel cell technology. Hydrogen development and research, then, will produce facilitating technologies that can be used to spur development and create a boom in fuel cells. Similarly, a major barrier to the marketability of superconductors is the lack of adequate cryogenic technology. If that technology can be developed, superconductors could revolutionize the way we transmit power, completely changing our readiness to handle growth, and even the cosmetic appearance of our cities and neighborhoods.

Roadmap

We will discuss the following technologies and their concomitant facilitating and enabling technologies in the following order:

- **Renewables**
- **Microturbines**
- **Fuel Cells**
- **Superconductors**.

Between the discussion of renewables and microturbines, we offer a synopsis of distributed generation, which will set the context for the analysis of microturbines and fuel cells.

In each technology chapter, we provide a very detailed (and somewhat technical) description of each technology. Then, we conduct an industry and market analysis for the technology under scrutiny. We list the companies in the industry, along with financial analysis of each. We list Utah's companies and resources, and make recommendations for development, research, and commercialization of the technologies within the State of Utah, and also make specific recommendations on which companies we should contact and pursue as possible anchors for a high-tech, advanced alternative energies sector in Utah.

We follow our analysis of each technology segment with a Plan of Action, and a concluding summary chapter.

We hope you will find the report useful.

Renewable Energy

Powering Tomorrow

"Renewable and alternative energy supplies not only help diversify our energy portfolio; they do so with few adverse environmental impacts."

National Energy Policy Development Group
In *National Energy Policy*, May 2001

As residential, commercial, and industrial demand for clean, reliable energy has increased; and the utilities industry has experienced deregulation, there has been an increasing amount of demand for green power—solar, wind, geothermal steam, biomass, and small-scale hydroelectric sources of power.

The application of renewable energy is an excellent way to diversify Utah's energy portfolio. Utah has traditionally focused on the obvious forms of power based on their natural resources. Utah produces high-quality coal and in the past, has been able to keep their energy prices at a reasonable level. However, based on energy challenges in other geographic areas and in the increased demand for power in Utah, now is the time to diversify power production and consumption. Utah is experiencing high-tech growth at a fast rate, and high tech industries are "power hogs" that require massive amounts of reliable energy. An administrator at Pacificorp explained this well. He pointed to a tall building in Salt Lake City and said that if that building was housing companies with a high demand for computer/internet usage, that the energy required for that building would increase by 20 times. Given the Governor's initiative to continue the technological growth in Utah, we will naturally need more power.

Nationwide, the five leading states for utility renewable electricity generation are: Washington, California, Oregon, New York, and Alabama, which account for 60 percent of renewable energy produced, the majority of which comes from hydroelectric power. California has been a leader in developing renewable energy production. They have focused a lot of time and money into expanding this industry. The state has especially focused on solar, geothermal, and wind renewables to replace the high fossil fuel usage. It is a valuable prototype for us to examine, as there have been effective and ineffective actions taken in regards to incentives, emissions laws, and cooperation among business and government.

The five leading states for non-utility renewable generation are: California, Florida, Maine, Alabama, and New York, which account for 45 percent of total non-utility energy produced, the majority coming from biomass except in California, which has geothermal resources on a scale unmatched anywhere else in the United States, (Energy Information Administration, www.eia.doe.gov).

Renewable Energy Generation and Consumption

Generation

In the non-utility sector, 1998 energy production was clearly led by biomass resources, followed by hydroelectric. In the utility sector, hydroelectric power accounted for more than 98 percent of 1998 energy production. It is interesting to note that hydroelectric utility generation decreased from 1997 to 1998, largely due to the deregulation of the utilities industry. Biomass in the utility sector has risen substantially in the past few years, as more plants have incorporated "co-firing" into their traditional practices.

Electricity Generation From Renewable Energy by Energy Source, 1994-1998 (1000 Kilowatt-hours)

Source	1994	1995	1996	1997	1998
Non-utility Sector (Gross Generation)					
Biomass	57,391,594	R57,560,556	R58,080,464	R55,278,582	53,744,724
Geothermal	10,122,228	9,911,659	10,197,514	R9,381,646	9,881,958
Hydroelectric	13,226,934	14,773,801	16,555,389	R17,902,435	14,632,521
Solar	823,973	824,193	902,830	892,892	886,553
Wind	3,481,616	3,185,006	3,399,642	R3,248,140	3,015,497
Total	**85,046,345**	**R86,255,215**	**R89,135,839**	**R86,703,695**	**82,161,253**
Electric Utility Sector (Net Generation)					
Biomass	R1,988,257	R1,649,178	R1,967,057	R1,983,065	2,024,242
Geothermal	6,940,637	4,744,804	5,233,927	5,469,110	5,176,280
Conventional Hydroelectric	247,070,938	296,377,840	331,058,055	341,273,443	308,843,770
Solar	3,472	3,909	3,169	3,481	2,518
Wind	309	11,097	10,123	5,977	2,957
Total	**R256,003,613**	**R302,786,828**	**R338,272,331**	**R348,735,076**	**316,049,767**
Total Net Imports	**28,844,268**	**26,648,933**	**31,673,157**	**R21,216,620**	**19,918,347**
Total Renewable Electricity Generation	**R369,894,226**	**R415,690,976**	**R459,081,327**	**R456,655,391**	**418,129,367**

Energy Information Administration, "Monthly Power Plant Report"; "Annual Nonutility Power Producer Report" (for 1998); "Annual Electric Generator Report-Nonutility"; and *Electric Power Annual 1998, Volume II*, (Washington, DC, October 1999). Personal communication with Dave Walker of Natural Resources Canada (Ottawa, Canada, March 1999). U.S. Department of Energy, Office of Fossil Energy, "Annual Report of International Electricity Export/Import Data."

Consumption

In the U.S., renewable energy consumption reached 7.032 quadrillion BTUs in 1998, which accounted for 7.5 percent of the total energy consumed. Hydroelectric power was the leading renewable, followed by biomass. Renewable energy has grown at a 2.4-percent annualized rate since 1994.

> ***"Energy consumption is increasing exponentially above energy production."***
> ***Orrin Farnsworth, Intermountain Solar Technologies***

There was a small decline in the drop of consumption of hydroelectric power from the electric utility sector, which was nearly ten percent lower in 1998 than in 1997. Consumption in other sectors remained largely unchanged. Industrial sector consumption rose 1.6 percent, largely as a result of a 2.9-percent increase in biomass energy. Excluding hydroelectric power, renewable energy consumption rose by 2.2 percent in 1998.

Consumption of alternative energies will rise dramatically as Californians, and others experiencing power shortages, turn to renewable options. The society that we live in today is very much dependant on reliable power to sustain the dramatic increase in energy-sucking high-tech industries. California already turns to Utah and other states to import the power that the state demands.

Renewable Energy Consumption by Sector and Energy Source, 1994-1998 (Quadrillion Btu)

Sector and Source	1994	1995	1996	1997	1998
Residential/Commercial					
Biomass	0.582	0.641	0.644	0.475	0.468
Solar	0.064	0.065	0.066	0.065	0.065
Geothermal	0.010	0.011	0.012	0.013	0.015
Total	**0.656**	**0.717**	**0.722**	**0.553**	**0.547**
Industrial					
Biomass	R2.217	R2.286	R2.370	R2.389	2.459
Geothermal	0.214	0.210	0.217	R0.200	0.210
Conventional Hydroelectric Power	0.136	0.152	0.171	0.185	0.151
Solar	R0.009	0.008	0.009	0.009	0.009
Wind	0.036	0.033	0.035	R0.033	0.031
Total	**R2.613**	**R2.690**	**R2.802**	**R2.816**	**2.860**
Transportation					
Biomass	0.097	0.104	0.074	0.097	0.105
Electric Utility					
Biomass	R0.021	0.017	0.020	R0.020	0.021
Geothermal	0.145	0.099	0.110	0.115	0.108
Conventional Hydroelectric Power	R2.549	R3.056	R3.421	R3.519	3.184
Solar and Wind	*	*	*	*	*
Net Renewable Energy Imports	0.310	0.284	0.334	0.219	0.206

Total	**R3.024**	**R3.457**	**3.886**	**R3.873**	**3.520**
Total Renewable Energy Consumption	**R6.390**	**R6.968**	**R7.483**	**R7.339**	**7.032**

1994-1996: Energy Information Administration (EIA), *Annual Energy Review* 1998, (Washington, DC, July 1999), **1997 and 1998:** Electricity Consumption--EIA, *Electric Power Annual 1998, Volume II,* (Washington, DC, October 1999). Non-electricity Consumption (except imports)--Based on analysis by the Office of Coal, Nuclear, Electric and Alternate Fuels. **Net Renewable Energy Imports, 1994-1998:** Based on analysis by the Office of Coal, Nuclear, Electric and Alternate Fuels.

Current Issues in Utah

Current energy issues in Utah include increasing power costs, growing demand for energy in high-tech industries, and the "branding" of Utah as an oasis for high-tech business. These factors are interrelated, where changes in one have both short and long-term effects on other factors.

"Is this only a Micron-PacifiCorp issue, or is it an issue of a power shortage that will affect all industry in Utah?" *Micron spokesman Stan Lockhart*

An excellent example of how Utah's high-tech industry future is tied to its energy industry is the Micron-PacifiCorp feud.

Micron Technology is battling a proposed rate hike of "well over five times" the current price. Leaders at Micron Technology wonder if California's power woes have rolled into Utah, creating a shortage, or if PacifiCorp is taking seeking a higher profit margin because of their position as Micron's sole power provider. Micron has filed a complaint with Utah's Public Service Commission regarding PacifiCorp's intent to change the terms of a contract the companies have operated under for five years.

"The fight over power in front of the Public Service Commission may send a message to other high-tech companies that Governor Mike Leavitt hopes to lure to Utah. Warnings of battles with power companies could give some of those companies pause about relocating here." *Stan Lockhart, Micron spokesman*

Micron needs about 11.5 kilowatts of electricity and it is anticipated that their energy demand will increase to about 15 kilowatts over the next two years. PacifiCorp is the sole utility provider to Micron and "any discontinuation of electric service would cause Micron and its Utah employees grievous economic harm,"(Brice Wallace and Jeffrey Haney, *Deseret News*, "Micron puts up fight over power rate hike").

Lehi city, which provided power during the plant's construction, doesn't currently have the resources to provide the power the company needs.

Micron said that last year it told PacifiCorp it would need additional electricity, and PacifiCorp responded by saying it could not support Micron's request and that improvements would be needed to meet any increased capacity. The companies then agreed to have Micron pay for construction of a distribution line from Micron's Lone Peak Substation to PacifiCorp's Camp Williams Substation in Bluffdale in return for any electricity from the Camp Williams Substation through the new line to the Lone Peak Substation (free of charge to Micron).

Micron spokesman Stan Lockhart said, "The fight over power in front of the PSC may send a message to other high-tech companies that Gov. Mike Leavitt hopes to lure to Utah. Warnings of battles with power companies could give some of those companies pause about relocating here. That's the heart of the matter as far as we are concerned."

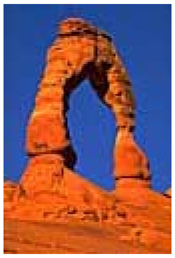
PacifiCorp earlier this year faced a complaint from another large power user. Part of the power contract dispute between Western Electrochemical Co. and PacifiCorp was settled in April. (Brice Wallace and Jeffrey Haney, *Deseret News*, "Micron puts up fight over power rate hike").

Micron has contacted the State of Utah Energy Office to pursue alternative form of energy. They specifically spoke of using wind turbines to produce power.

The truth of the matter is that Utah has great coal, and the incentives are not in place to encourage alternative energy growth. An *alternative energy tax credit* and *net metering bill* could change the incentive structure. Right now, the incentive is to exploit further our vast coal supply and to produce power as inexpensively as possible. The natural applications for renewable forms of energy are market niches—remote areas and situations where power is too costly, as in the Micron case.

In order for Utah to become a "high-tech oasis", energy must be reasonable priced, reliable, and sustainable. Utah has a great tradition of research. These institutions should pursue funding from various organizations and government bodies to research alternative forms of energy production, and, we should access the research already being done. For example, the Center for Coal Combustion at BYU is the best in the world. Coupling combustion research with applied co-firing of coal and biomass would be an excellent usage of the competitive advantage in coal combustion already in place.

Utah Energy



Determining the effectiveness of encouraging the development of Utah's renewable energy market necessitates analysis of the renewable energy industry, and Utah's stage of alternative energy development and the potential job and wealth creation with expansion in certain segments of the industry.

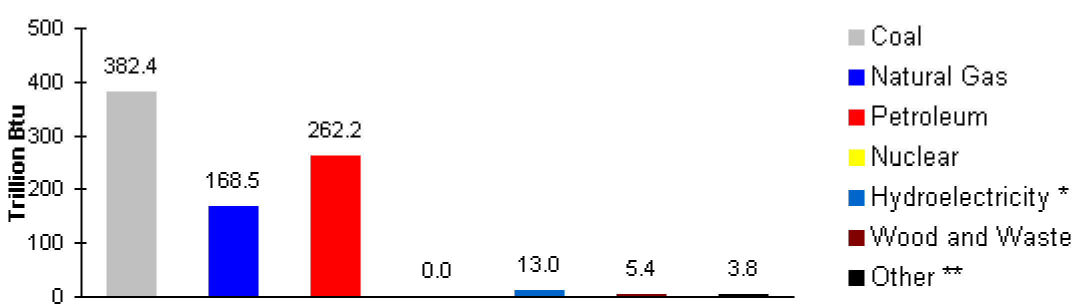
A Quick Look at Utah Energy

- Utah ranks 12th among all States in production of crude oil, 12th in natural gas, and 14th in coal
- To meet its own energy requirements, Utah relies on coal, followed by petroleum, natural gas, and small amounts of hydroelectricity and biofuels
- Ninety-four percent of the State's electric utility fuel supply is coal; hydroelectric power, natural gas, and geothermal power account for the remaining 6 percent
- Utah's rate of expenditures for all energy per person is the lowest in the Nation
- If all the State's wind energy potential was developed with utility-scale wind turbines, the power produced each year would equal 171% of the entire state's electricity consumption

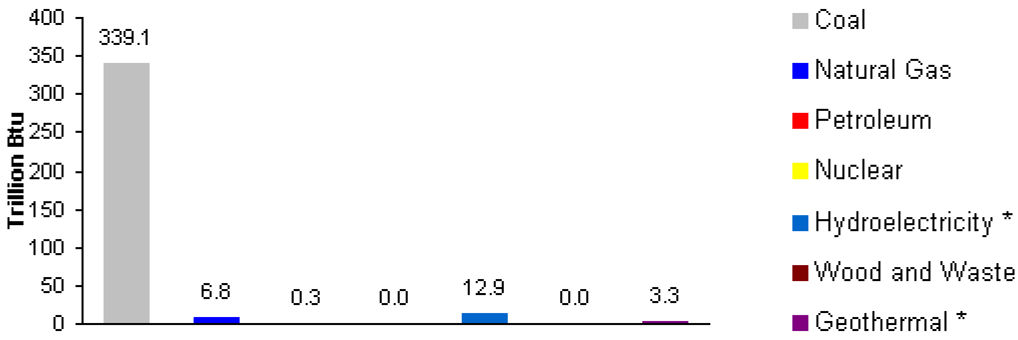
(Energy Information Association, www.eia.doe.gov)

As shown on the following charts, Utah is a coal producing and consuming state, coal being the number one source of energy for electric utilities. The key factors for encouraging alternative forms of energy development will be incentive structure, profitability, and feasibility.

Utah, Primary Energy Consumption, 1999



Utah, Electric Utility Use, 1999



(Energy Information Association, www.eia.doe.gov)

Utah, compared to the nation, consumes 0.7 percent of all energy and 1.9 percent of total coal consumption.

Utah Rankings of Consumption	Rank	Share of U.S. Total (%)
Total Energy	36	0.7
Coal	22	1.9
Natural Gas	33	0.8
Petroleum	34	0.7
Electricity	39	0.7
Residential Use	36	0.7
Commercial Use	34	0.8
Industrial Use	35	0.7
Transportation Use	35	0.8

Utah's energy prices are the 6th lowest in the nation (as calculated in 1997). Natural gas and coal were both inexpensive energy resources compared to the costs nationwide. "Power costs 6.8 cents a kilowatt plus tax in Utah…the wholesale cost of power in California is now 25 cents a kilowatt plus tax and is forecasted to reach $1-2 kilowatt. The average urban homes take 1000 to 2000 kilowatt,"(Orrin Farnsworth, Intermountain Solar Technologies). This opens up a natural opportunity for Utah to sell its excess energy to states like California.

Utah Energy prices and rankings	State	United States	Rank
All Energy	7.58	8.82	44
Motor Gasoline	10.39	9.73	12
Petroleum	8.77	7.82	9
Natural Gas	3.83	4.62	43
Coal	1.02	1.31	44
Electricity	15.25	20.15	45

As far as energy expenditures, Utah ranked 36th in the nation with petroleum being the largest. Although fewer dollars were spent on coal, it accounted for a higher percentage of the U.S. total.

Utah Expenditures	Billion Dollars	Share of U.S. Total (%)	Rank
Total Energy	3.7	0.7	36
Petroleum	2.1	0.8	34
Motor Gasoline	1.2	0.8	34
Natural Gas	0.5	0.6	37
Coal	0.4	1.4	27
Electricity	1.0	0.5	41

(Energy Information Association, www.eia.doe.gov)

Utah's Renewable Energy Future

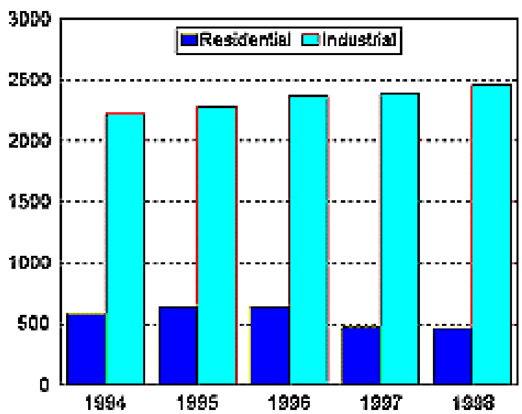
Utah's renewable forms of energy can be organized in the following categories: *Bioenergy*, *Geothermal*, *Hydropower*, *Solar*, and *Wind*. These technologies can all be developed further in Utah. However, as we have limited resources to invest in alternative energies, we have recommended actions to take based on Utah's advances in the industry, natural resources, and reasonability of initial and continued costs.

Each renewable energy is described below followed by an industry analysis of how the respective industries complement Utah's natural resources and competitive advantages. Following the analysis is a list of key companies in the renewable energy industry. These companies would be valuable to examine as potential recruits. In addition, we have inserted profitability ratios for the industry compared to the U.S. market as a whole. We have also included a list of companies already in Utah.

Bioenergy

Bioenergy is used to produce a variety of energy products including: electricity; liquid, solid and gaseous fuels; heat; chemicals; and other materials. With more than 7,000 megawatts of installed capacity, bioenergy ranks second (to hydropower) in U.S. renewable energy forms. The 37 billion kW hours produced each year from bioenergy accounts for 3 percent of the energy production in the U.S., which is more than the state of Colorado uses annually. This requires 60 million tons of biomass a year, (Energy Efficiency and Renewable Energy Network—EREN, Department of Energy, www.eren.doe.gov).

U.S. Biomass Energy Consumption by Major Sectors, 1994-1998



The U.S. biomass energy consumption is largely made up of industrial users. Biomass consumption has grown consistently from 1994 to 1998, (Energy Information Administration, *Annual Energy Review 1998*, Washington D.C.).

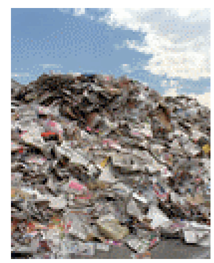
Bioenergy can be converted into electricity (or heat) in one of several processes. Today, the most common way is by using a steam cycle. This works by converting biomass material into steam in a boiler; the steam then turns a turbine which is connected to a generator. This is popular because biomass can also be burned together with coal to produce power in existing power plants. This is called "co-firing". This is a good option as it is the most economical near-term option, and it lowers the air emissions from coal-fired plants.

Another option is to convert solid biomass into a fuel gas. Biomass gasifiers, such as the one shown in the picture on the left; in Maui, Hawaii; are attracting attention with the emergence of high efficiency turbine systems and fuel cells. This particular facility converts sugarcane residue into gas, (PICHTR facility, taken from the National Renewable Energy Laboratories picture collection).

Bioenergy Terms and Technologies

- Biomass—any plant-derived matter available on a renewable basis. This includes agricultural crop residues, wood residues, animal wastes, energy crops, and municipal waste materials. Residues, the organic byproducts of food, fiber, and forest production, are the most economical biomass fuels for generating electricity. Examples include sawdust, rice husks, and bagasse (the residue remaining after juice has been extracted from sugar cane). Used shipping pallets and yard trimmings are also good low cost sources of biomass and are common near population and manufacturing centers. In the future, much larger quantities of biomass power could come from fast-growing trees, "energy crops", forest debris, agricultural wastes, animal manures, and landfills.

- Biopower—electricity generation based on direct-combustion; future improvements will include co-firing of biomass in existing coal-fired boilers, and eventually, fuel cell systems and high-efficiency gasification combined-cycle systems.



- Biofuels—a variety of fuels made from biomass resources. Liquid fuels include: ethanol, methanol, and biodiesel. Gaseous fuels include: hydrogen and methane. Biofuel research is focused on production, application, and distribution of the fuels.

- Bio-based chemicals and materials—includes green chemicals, renewable plastics, natural fibers, and natural structured materials. With further development, many of these products can replace chemicals and materials originally derived from petrochemicals.

Utah's Bioenergy Resources

> ***"Five to ten percent of energy consumption in Utah could be produced by biomass."*** *Dr. Larry Baxter, BYU Combustion Center*

Utah's competitive advantage lies in the fact that it is a big coal state. Utah has naturally good, and comparatively clean coal, especially in the eastern areas of the state. This natural resource has led to the development of many coal-fired power plants. There is an opportunity for biomass, because the most practical and cheapest applications of biomass combustion are co-fired applications that require both coal to burn and coal-fired plants in which to burn it.

In addition, BYU's Combustion Center is the best in the world and Utah has a lot of farmland that produces agricultural residues as a by-product.

"Utah has a very high-quality coal because of its density and BTU content. The coal is hard enough to have lots of BTU generating capacity, but brittle enough that it can be ground up for use in the pulverized coal-fired plants,"(Dr. Val Finlayson, formerly with Utah Power and Light—20 years).

"Biomass power production using co-firing processes is the future of the industry…Utah is in an optimal position to be the world leader in biomass power production, as well as in development,"(Dr. Larry Baxter, BYU Combustion Center). Utah, as a big "clean coal" producer, with its almost exclusive reliance on coal-fired power production, stands to make big gains by investing in biomass development.

In addition, because biomass can help make coal cleaner, we can market power for export as relatively inexpensive "green power" to states whose environmental laws are prohibitive, or who lack cheap coal-fired power. Utah already exports a lot of coal-produced electricity to environmentally conscious states like California. Having greener power is a great marketing strategy for selling electricity at a higher price.

"Biomass power production using co-firing processes is the future of the industry…Utah is in an optimal position to be the world leader in biomass power production." Dr. Larry Baxter, BYU Combustion Center

Wasatch Energy Systems in Layton are currently "burning" municipal waste to produce energy and to help Utah's waste management.

In addition, the Energy Recovery Unit on the east side of Hill Air Force Base is "burning" garbage in their old boilers at lower temperatures and pressures than normal. An incentive problem exists because it is inexpensive to handle waste at a landfill—the going rate is $6.00/ton, so the cost of processing the garbage instead is too great.

Recommendations for Bioenergy

DEVELOP CO-FIRING OF COAL AND BIOMASS BY COUPLING COMBUSTION CENTER RESEARCH WITH COAL POWER PLANTS

Steps to Take

- **Capture federal/state research dollars for biomass.**

Catalyze the capture of federal research dollars for biomass in Utah, and funding for the minor modifications of coal-fired plants necessary to producing greener power. In addition to

federal funding, there are some opportunities to receive dollars from other states to develop and sell green energy. Dr. Larry Baxter has connections with the California Energy Commission and he mentioned that they would probably be interested in working on a project together and providing some funding, with biomass plants in Utah.

- **Encourage relationships with research institutions and industry—Governor Leavitt appointed "Biomass Task Force."**

Task forces, conferences and university/government/industry-sponsored energy technology fairs are a good way to bring people together (under "***Bioenergy Expert Contacts***" is a list of key contacts). BYU's Center of Combustion and the University of Utah's Center for Advanced Combustion are excellent resources that should be encouraged to work with industry. Dr. Larry Baxter would be an excellent choice to lead such a task force. There are projects that professors are already working on—for example, BYU is working to decrease pollutants of coal production near the campus.

A possible target could be an intermountain power project in Delta. That plant is currently using all coal. Many plants in the state could be co-firing biomass with coal.

Utah would develop a need for "fuel brokers" to find good sources of biomass for a reasonable price. Biomass is sold as a commodity on exchanges such as the Chicago commodities market.

- **Have more stringent environmental regulatory standards.**

> ***"Utah's energy future appears to lie in our capacity to develop coal resources and coal combustion in coal-fired power plants. "*** *Dr. Val Finlayson, formerly with Utah Power and Light—20 years*

Without environmental standards or financial motivations, companies do not have incentives to pursue these more costly sources of energy. The government has a legitimate role in protecting the environment and people's health. To the degree that environmental laws are legitimate, they do not distort the market or create artificial markets. They act to correct market failure (externalities associated with production of "dirty" energy). The way to do that is, instead of making specific regulatory requirements of power producers, state standards should make portfolio requirements, setting a standard for emissions or a specific amount of reduction expected, and allow the companies to determine how they will meet that standard. Innovations, increases in efficiency, and business improvements will naturally develop as companies try to meet new emissions standards without being told exactly "how." Portfolio standards are the least market-distorting types of regulations.

- **Increase energy prices.**

    Without a price increase to lessen the difference in price between coal-generation and co-firing, consumers will not demand it. The tradeoff is too large.

- **Tax incentives to power companies.**

    Tax incentives to power companies who use green power may help them offset the costs of producing the more expensive types of alternative power. But it does not necessarily raise the price of power, just the tax burden of the state.

- **Market green power in Utah.**

Marketing green power is the least effective strategy, since Utah consumers do not have a choice of where they buy their power, and if they did, they would likely choose the cheapest, not the cleanest energy provider.

Costs of Bioenergy

Bioenergy is relatively expensive compared to traditional energy production. However, in developing and using co-firing processes, we may be able to market greener energy to states where they have an interest in purchasing power from non-polluter states.

Biomass is very expensive to produce. Energy crops require lots of energy and time to raise, so they are not very practical. Bioenergy costs from $200 to $300 a kilowatt-hour to produce. For comparison, coal costs about 3 to 4 dollars per ton for the coal wholesalers. It costs 10 to 15 dollars to the power companies. The wholesale price of the cheapest agricultural commodity currently produced in the US is 45 to 50 dollars per ton. The reason that biomass is costly is that it is expensive to transport because it is 1/10 as dense as other resources, such as coal. The transportation costs add about $20 a ton. Bioenergy is not competitive with fossil fuels as a means of producing electricity if we look at it under the strictest measurements.

However, developing more bioenergy production wouldn't be that capital intensive because of Utah's existing power plants. Economies of scale would also lower the costs of producing bioenergy. Wood residues, lawn trimmings, and orchard trimmings are the highest quality of biomass. Agricultural residues are good; however, rice is very hard on the boilers. As Larry Baxter put it, "I wouldn't put sugar in my gas tank and power plants don't want to put rice in their boilers".

Furthermore, a sort of artificial market has developed because of tougher environmental regulations in California for new power sources that are cleaner, where comparative cost is not such a huge factor.

Bioenergy Environmental Issues

Biomass technology can be most easily applied in a co-firing strategy, together with coal. Co-firing a mixture of ten percent Biomass with about 90 percent coal can significantly reduce the CO2 emissions. The sulfur byproduct of coal combustion works to neutralize the harmful byproducts of burning Biomass. The result of co-firing is a much “greener” coal-fired power source.

To be in compliance with Keota suggestions, bioenergy is an excellent option. “Biomass can fill one-half of the pollution reduction due by 2008…this is the single largest contribution…in addition, biomass is 100 percent renewable,” (Dr. Larry Baxter, BYU, Dept. of Chemical Engineering).

Bioenergy Expert Contacts

- Larry Baxter, Ph.D., BYU, Dept. of Chemical Engineering, 801-378-8616 (interviewed and attended energy summit)
- Kevin Witty, Ph.D., University of Utah, Kennecott Research Center
- Dave Pershing, Academic VP, UofU (referred by Larry Baxter, very strong combustion background)
- Douglass Smoot, BYU, Dept. of Chemical Engineering, 801-378-8930 (attended energy summit)
- Kevin Whitty, UofU Kennecott Research Center, Dept. of Chemicals and Fuels Engineering, 801-585-9388 (present at interview with Dr. Larry Baxter)
- Eric Eddings, BYU (referred by Dr. Larry Baxter)
- Dale Tree (referred by Dr. Larry Baxter)
- Tom Fletcher (referred by Dr. Larry Baxter)
- Joanne Lytee, BYU (referred by Dr. Larry Baxter)
- Sandia National Laboratories, Combustion Facility, CA (largest combustion center in the world, Dr. Larry Baxter was previously working for them)
- California Energy Commission (Dr. Larry Baxter has contacts there)
- Renewable Resource Data Center

Geothermal

The word “geothermal” is based on the Latin words “geo” (earth) and “thermal” (heat). As can be deduced from the name, geothermal energy is power obtained by the earth's natural heat, and is extracted for heating purposes and electricity generation in forms of steam, hot water, or hot dry rocks. The process is fairly uncomplicated. As the earth's temperature increases with depth, 4,000 to 15,000 foot wells are drilled and water is pumped down through an injection well where it passes through cracks in hot rocks. The resulting heated water rises to the surface through a recovery well and may be converted to steam or run through a heat exchanger. Dry steam may be directed through turbines to produce electricity; this is an especially important source of energy in volcanically active areas, (U.S, Dept. of Energy, Geothermal Energy Technical Site).

Geothermal energy technologies use the heat of the earth for direct-use applications, geothermal heat pumps, and electrical power production.

There are many direct-use applications for geothermal heat. The world's largest geothermal heating/cooling system is located at the Galt House East Hotel and Waterfront Office Buildings in Louisville, Kentucky. The 750,000-square-foot Galt House East Hotel uses a 1,700-ton system, which cost $1,500 per ton to install. In comparison, a conventional system would have cost between $2,000 and $3,000 per ton. As a bonus, the system saves about $25,000 per month in reduced energy costs and frees up about 25,000 square feet of additional commercial space that would have been needed to house conventional equipment. In addition, the 960,000 square foot Waterfront Office adds almost 3,000 tons of capacity to the project. According to Marion Pinckley, Galt House designer and construction manager, "Galt House East has been running for 15 years with no system problems…the system has performed even better than expected," (National Renewable Energy Laboratories).

An interesting example of geothermal heat applications is the Colorado Alligator Farm in Mosca, Colorado. The farm uses low-temperature geothermal heat to keep their alligators warm throughout the year. In addition, most of us have enjoyed the warm water from hot springs. There are many resorts built around these pockets of geothermal heat.

Whereas geothermal energy can be used in direct-use applications, to heat buildings, pools, and industrial processes; it also has tremendous potential for producing electricity. Research in all areas of geothermal development is helping to lower costs and expand its use. In the United States, most geothermal resources are concentrated in the West, but geothermal heat pumps can be used nearly anywhere. Geothermal power production produces much lower air emissions than conventional energy technologies, (Energy Efficiency and Renewable Energy Network—EREN, Department of Energy, www.eren.doe.gov).

Geothermal Terms and Technologies

- Direct Use—Geothermal hot water near the Earth's surface can be used directly for heating buildings and as a heat supply for a variety of commercial and industrial uses. Geothermal direct use is particularly useful for greenhouses and aquaculture.

- Geothermal Heat Pumps—Ground-source heat pumps use the relatively constant temperature of soil or surface water as a heat source for a heat pump, which provides heating and cooling for buildings. Geothermal heat pumps produce heat more efficiently than furnaces, boilers, and air-source heat pumps.

- Electricity Production—Underground reservoirs of hot water or steam, heated by magma, can be tapped for electrical power production. In the United States, high- and medium-temperature geothermal resources for electricity production are located in the West. Current power plants for generating electricity from hydrothermal resources can be divided into two general types: steam and liquid. Steam plants are typically used with higher-quality, higher temperature resources, as found at the geysers in Northern California. In these plants, steam from the wells is expanded through a turbine that drives an electrical generator. With lower-quality, liquid-dominated resources, it is usually more cost-effective and efficient to transfer heat from the geothermal fluid to a volatile working fluid. In this process the fluid is vaporized, expanded through a turbine driving an electrical generator, condensed, and pumped back to the heat exchangers completing a closed cycle. The steam plants are less costly than the liquid-dominated geothermal energy generation.

- Advanced Technologies—Advanced technologies will help manage geothermal resources for maximum power production, improve plant operating efficiencies, and develop new resources such as hot dry rock, geopressured brines, and magma.

- Hot Dry Rock: Some geothermal resources, deep underground, hold no water and are referred to as hot dry rock. The U.S. geothermal program operated a facility in New Mexico to pump water into a hot dry rock reservoir and extract its heat. Although the United States is not currently pursuing this technology, research continues in other countries.

- Geopressured Brines: Hot methane-rich brines under high pressure are located along the Gulf Coast of the United States. U.S. research into extracting energy from these "geopressured brines" culminated in 1992 with the operation of a pilot power plant in Texas. Research continues in other countries and there has also been research done to extract energy from the Great Salt Lake.

- Magma Energy: Extracting heat directly from magma has the potential to supply vast amounts of energy. U.S. research in magma has been limited, but research continues in other countries.

- Drilling—locating geothermal resources has been adapted from the oil industry. Improvements in drilling technologies will be influential in developing geothermal energy as an alternative energy source.

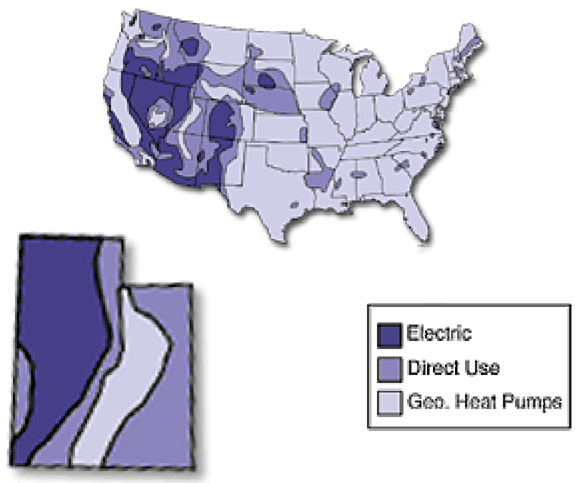
The National Renewable Energy Laboratory (NREL) is a leader in geothermal research for the U.S. Department of Energy's Geothermal Energy Program. The NREL works with the DOE and with industry partners in geothermal research and development efforts. One of their main focuses is on lowering the electric energy cost of geothermal power plants. Geothermal energy currently accounts for about 7,000 megawatts of electricity produced throughout the world, including about 2,800 megawatts in the United States. All geothermal electricity generation comes from hydrothermal (hot water/steam) resources.

Although geothermal power plants share many attributes with more conventional power plants, they also have unique features that pose special challenges. Research and development targeting improved plant performance and lowered manufacturing costs can greatly impact the delivered electricity costs of geothermal power plants and can provide spin-off improvements applicable to conventional plants.

Utah’s Geothermal Resources

Hydrothermal resources (reservoirs of steam or very hot water) are well-suited for electricity generation. Earth energy, the heat contained in soil and rocks at shallow depths, is excellent for direct use and geothermal heat pumps. Direct-use applications require moderate temperatures; geothermal heat pumps can operate with low-temperature resources.

As indicated on the map, Utah has high-temperature resources that are suitable for electricity generation in the western half of the state. In fact, Utah is one of just a few states in the U.S. where high-temperature geothermal energy is located. Every geothermal site has a unique set of conditions and the plant design must match the type and temperature of the particular resource. For example, the fluid produced from a geothermal well can be steam, brine, or a mixture of the two; and the temperature and pressure of the resource can vary considerably from site to site.



Utah geothermal resource

Department of Energy, Denver Regional Office

Utah also has many direct-use resources and geothermal heat pump potential. Direct-use resources can be used to provide heat in a variety of applications. The versatility and inexhaustibility of these resources make it attractive for municipalities, as well as individuals and businesses. Geothermal heat pumps are similar to conventional air conditioners and refrigerators. They are among the most efficient, and therefore least polluting, heating, cooling, and water-heating systems available.

Utah currently has two operating geothermal plants, Provo Power owns one in Cove Fort (37 kilowatts) and UP&L owns one outside of Milford (20 megawatts); whereas, most coal-fired plants are operating on the scale of about 400 megawatts. Cove Fort is a “dry steam” site, wherein power is generated from high-pressure steam trapped in pockets deep in the ground. Milford has wet steam, which is a combination of very hot water and steam. The Milford plant provides power to approximately 20,000 people in south-central Utah.

Stanford University has estimated that the Milford plant may have up to 100 megawatts of generating capacity. That is 80 megawatts more that what is currently being exploited. Stanford has offered to determine the exact operating capacity if supplied with ten years of well operating data.

The Colorado School of Mines and Stanford University have performed surveys all over the state to locate the geothermal “hotspots”. They drilled wells in both Brigham City and Buryl. They found hot water under high pressure. It wasn’t hot enough to produce electricity; however, these resources are good for year-round agriculture production in greenhouses and food processing. There are many hot springs located up and down the Wasatch Front (Val Finlayson, Ph.D., Utah Partnership, formerly with Utah Power and Light for 20 years and Los Alamos National Laboratories).

With advances in geothermal technology, there may be many other sites in the state where electrical power could be produced. Neldon Johnson, of International Automated Systems (stock symbol IAUS) may be able to put Utah on the map with his patented geothermal turbine invention. He is currently in the process of signing a contract with PacifiCorp where he will receive one penny for every kilowatt produced. PacifiCorp is asking that they have an exclusive relationship in the western United States to prevent other power companies from using the technology (Merrill Brimhall is their PacifiCorp contact). Neldon already has an agreement with New Mexico to produce power for one penny per kilowatt. In addition, Los Alimos Laboratories have agreed to work with his geothermal turbine to perfect his patent/process. Dave Winder, of the Utah Department of Community and Economic Development has met with Neldon and spoke with him about the many technologies he is involved in.

> ***"A barrier to the acceptance of new technologies is the retailer…however, the consumer makes the ultimate choice…it is essential to market to them."*** ***Neldon Johnson, International Automated Systems***

Neldon's geothermal turbine is a unique "marriage" between rocket ship technology and the existing geothermal turbines. The turbine is designed to burn hydrogen and oxygen (making steam) and has a nozzle on the end imitating rocket ship technology.

Neldon's geothermal turbine, at the very least, matches efficiency rates of existing PacifiCorp plants at low temperatures; and is more efficient at higher temperatures. At 1500 degrees, his turbine has an efficiency rate of 68%.

Neldon is looking into the option of receiving a grant for any "clean energy" he can produce above and beyond what is currently being produced at the Milford plant. His company recently purchased some land in southern Utah containing hot springs and they are planning on starting a geothermal plant there.

Recommendations for Geothermal

ENCOURAGE GROWTH IN GEOTHERMAL TECHNOLOGIES AND USE CURRENT RESOURCES AT THEIR POTENTIAL

Steps to Take

- **Encourage growth in geothermal technologies in industry.**

Neldon Johnson's patented geothermal turbine should be further examined. As the contractual agreement with PacifiCorp is put into action, Neldon's technologies will be in the limelight of energy news. He has has preliminary contracts with several countries outside of the U.S. The State of Utah would do well to know what kind of global ramifications his technology could have.

This type of technology would be valuable for the State of Utah to invest in. At the very least, it would be good to help Neldon receive some federal funding for the research he is doing.

An opportunity also exists with the National Renewable Energy Laboratory's (NREL) National Alliance of Clean Energy Business Incubators. The NREL helps clean energy companies with their business plans and with investor and private sector financing. They also hold forums to encourage communication among businesses. Their contact information is under ***"Geothermal Expert Contacts***" and "***Renewable Energy Expert Contacts***".

- **Develop "mini" geothermal plants—distributed generation.**

Distributed generation is a "hot topic". The California energy crisis and rising National energy costs have encouraged many people to investigate non-traditional power generation options. The development of successful "mini" plants would have global implications. There are many remote areas in the world where this would be useful. Smaller, less-costly plants that don't have to be connected to the grid would encourage growth in rural areas and would encourage job growth in regions where energy-consuming industries couldn't locate otherwise.

Forming a task force with inventors, such as Neldon Johnson, and companies interested in on-site power generation, such as Micron, would spark growth in this technology.

- **Determine the capacity of the Milford plant and produce at capacity.**

Stanford University estimated that there is over 100 megawatts of operating capacity at the Milford plant; whereas, only 20 megawatts are being used. The Milford plant would need to provide well data for the past ten years and then Stanford would be able to determine the exact capacity. This is a project that they were willing to take on several years ago, (Val Finlayson, Ph.D., Utah Partnership, formerly with Utah Power and Light for 20 years and Los Alamos National Laboratories). Val would be a good contact for more information on initiating this project with Stanford.

Costs of Geothermal

Current steam plants cost about \$700-\$800 per kilowatt. The steam plants are less costly than the liquid-dominated geothermal energy generation. Liquid-dominated geothermal resource plants cost approximately \$1,500 per kilowatt.

Neldon claims that his geothermal turbine is less than a tenth of the cost of original turbines. It costs $100,000 to make the turbine and an additional $1 million to drill the well. A huge cost savings occurs because his turbine doesn't use cooling towers, which also reduces concerns over depleting aquifers. Geothermal energy is an excellent resource and the plants are "unmanned"(no laborers needed).

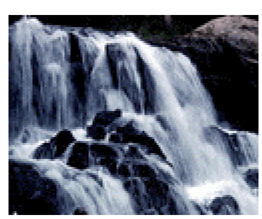
Geothermal Environmental Issues

Geothermal energy is an excellent environmental choice. There are miniscule amounts of hydrogen sulfide gas emitted during the production of geothermal energy.

Geothermal Expert Contacts

- Val Finlayson, Ph.D.; Executive Director, Utah Partnership for Education and Economic Developmet; formerly with Utah Power and Light for 20 years; Los Alamos National Laboratories; 801-538-8627 (interviewed)
- The National Renewable Energy Laboratory (NREL), located in Colorado, is a leader in geothermal research for the U.S. Department of Energy's Geothermal Energy Program. They also coordinate the National Alliance of Clean Energy Business Incubators and encourage clean energy businesses to contact them. Contact: Lawrence (Marty) Murphy, 303-275-3050 (CO) or Katie McCormack, 650-692-5254 (CA).
- Neldon Johnson, International Automated Systems, 801-400-0678 mobile phone (interviewed, inventor of a highly-efficient patented geothermal turbine)
- Merrill Brimhall, PacifiCorp contact of Neldon Johnson, (Neldon has worked with him for several years)
- Dr. Kenneth Cory, V.P. of Strategy, Calpine, 408-995-515 (attended the energy summit, Calpine is the national leader of geothermal energy production)
- Dr. Bill Burge, Utah State University, Chief Geologist from Milford drilling (referred by Dr. Val Finlayson)
- Stanford University Geothermal Research (contact Dr. Val Finlayson for details)

Hydropower



Hydroelectric power, the largest source of renewable energy, accounts for nearly ten percent of the electricity generated in the U.S. Worldwide, hydropower has the potential to supply 28 million homes with electricity, the equivalent of nearly 500 million barrels of oil. Current U.S. hydropower capacity is approximately 95,000 megawatts.

Hydropower is essentially the art of capturing energy created by flowing water and turning it into electricity. The most common method of capturing hydropower is with a *river or reservoir dam*. Water released from the reservoir flows through a turbine, activating generator to produce electricity. But hydropower doesn't necessarily require a large dam. Some hydropower plants just use a small canal to channel the river water through a turbine.

Another type of hydropower plant—called a *pumped storage plant*—can store power. The energy is sent from a power grid into electric generators. The generators then spin the turbines backward, pumping water from a river or lower reservoir to an upper reservoir, where the power is stored. To use the power, the water is released from the upper reservoir back down into the river or lower reservoir. This spins the turbines forward, activating the generators to produce electricity.

Facilities range in size from large power plants that supply many consumers with electricity to small and micro plants that individuals operate for their own energy needs or to sell power to utilities.

Hydropower Terms and Technologies

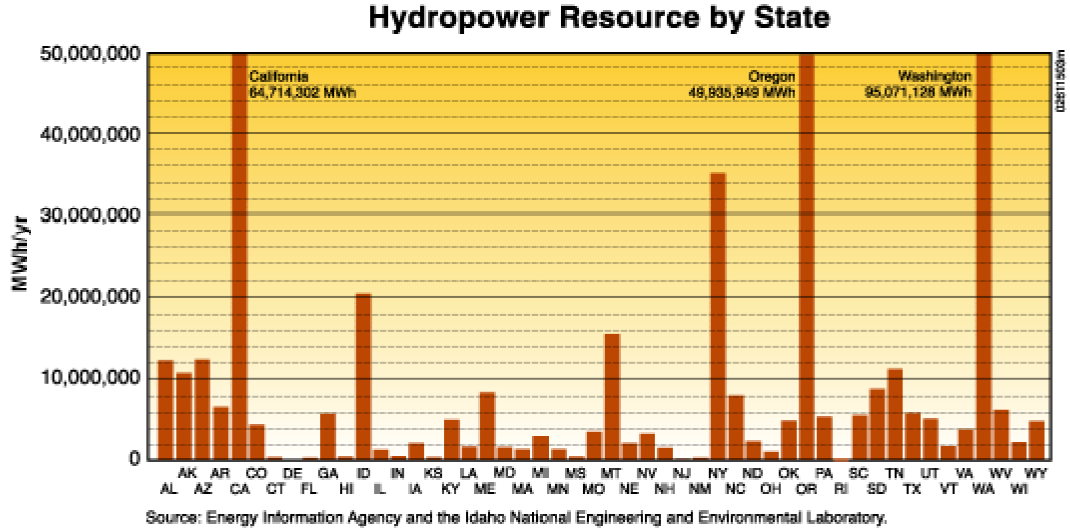
- Impoundment—An impoundment facility is typically a large hydropower system, using a dam to store river water in a reservoir. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level.

- Diversion—Sometimes called *run-of-river*, facility channels a portion of a river through a canal. It may not require the use of a dam.

- Pumped Storage—When the demand for electricity is low, a pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

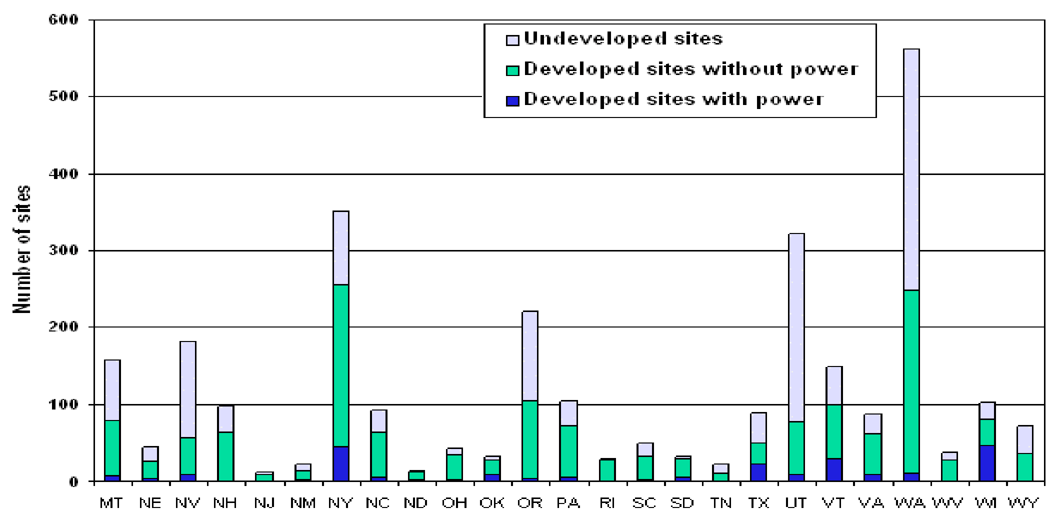
Utah's Hydropower Resources

Utah has a good hydropower resource as a percentage of the state's electricity generation. To have a useable hydropower resource, there must be both a large volume of flowing water and a significant change in elevation. Utah could produce an estimated 5,308,903 megawatts of electricity annually from hydropower. For comparison, this would represent 15 percent of the electricity generated from all sources in 1998 in Utah.



The chart above shows the overall hydropower resource by state, which includes both current hydropower generation and potential hydropower usage. This was calculated by factoring in the legal and environmental constrains on hydropower development, (Energy Information Agency, http://hydropower.inel.gov).

Following is a chart diagramming the developed and undeveloped hydroelectric sites by state (note that we have just included the chart that includes Utah—letters M to W). Utah ranks highly compared to other states. Apparently, there are approximately 230 undeveloped sites in Utah where hydroelectric power could be produced and approximately 80 developed sites where power isn't being produced, (Department of Energy, Hydropower Program). However, based on out interviews, there appears to be conflicting opinions on how much is available in the state.



Hydropower Program, U.S. Department of Energy

According to Dr. Val Finlayson, Utah Power and Light Administrator for twenty years, Utah has almost no unexploited capacity in hydroelectric power. However, there may be some potential for a pump plant on the eastern shores of Bear Lake. This was researched by UP&L in the 1970s.

The Utah State University Water Lab has done extensive research on hydro potential in Utah. Several years ago, in conjunction with UP&L, they made a map of all of the hydroelectric sites in the state. Dr. Val Finlayson was working for UP&L at the time and he told us that it might be possible to find the maps.

Recommendations for Hydropower

SMALL PRIORITY AND DOLLARS SHOULD BE SPENT ON PURSUING HYDROELECTRIC POWER IN UTAH; HOWEVER, CONCLUSIVE EVIDENCE SHOULD BE FOUND CONCERNING THE POTENTIAL AT BEAR LAKE

Steps to Take:

- **Contact the Utah State University Water Lab for records on hydroelectric sites.**

  If there are untapped hydroelectric resources in the state, it would be very valuable to locate and use them. According to Val Finlayson, Utah State University's Water Lab determined that there is potential to the east of Bear Lake. Potential barriers to developing a hydroelectric plant there may be resistance of the residents and any property laws prohibiting a power plant.

- **Contact the U.S. Department of Energy concerning their findings of hydroelectric potential in the state.**

  Apparently, the U.S. Department of Energy has determined that there are several untapped hydroelectric sites in the state. It would be interesting, and perhaps helpful, to see the areas they have targeted.

Costs of Hydropower

Modern hydroelectric technology has made hydropower a very efficient way of generating energy. Hydropower generation is at 90% efficiency in the process of electricity conversion.

With higher efficiencies, the costs of hydropower have gone down. Currently, hydropower is 7 cents a kilowatt hour,(Alternative Energy Institute, www.altenergy.org).

Hydropower Environmental Issues

Current hydropower technology, essentially emission-free, is an excellent “green” energy. The only undesirable environmental effects occur in fish injuries and mortalities from passage through turbines, as well as detrimental effects on the quality of downstream water.

Hydropower Expert Contacts

- Val Finlayson, 20 years with Utah Power and Light, State of Utah
- Utah State University Water Lab—for study of all hydro sites in the state
- Bill Berge—Ph.D. at USU. Formerly with Phillips when they studied hydropower
- U.S. Department of Energy, Hydropower Program

Solar

The sun, at 6000 degrees Celsius, is an outstanding natural heat source, even located as far as the earth is from the sun. Solar technologies use the sun's energy and light to provide heat, light, hot water, electricity, and even cooling, for homes, businesses, and industry. There are two main applications of solar power and heat: to generate electricity, or to warm water or other liquids.

Solar energy is produced in the following sequence:

Sun>Photovoltaic Panels>Batteries>Inverter>Transformed to AC

Basically, the solar panels help to convert electrons (energy) to DC electricity.

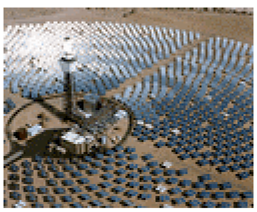
To the right is featured, “Solar Independence” of the NREL Visitors Center. This four-kilowatt flag-shaped photovoltaic (PV) system is the largest mobile system ever built. The blue section of the flag consists of PV panels that generate enough electricity for 1-2 homes. The red and white stripes are purely cosmetic. Located in the trailer behind the flag, are batteries that can store up to 51 kilowatt-hours.

The flag was on display on the Washington D. C. Mall April 24 to May 9 2001. "The objective is to raise people's awareness about the value of these technologies. And the only way to do that is to show them the technology," (John Thornton, engineer, the National Center for Photovoltaics (NCPV); the system was designed by NREL's Ben Kroposki).

It has been projected by BP Oil that by the year 2050, 50% of energy will have to be produced by alternative on-site methods. "There are currently160,000 households living on renewable energy in the United States…Solar energy is a cost-effective option in the long-run…it would be cheaper to pay the $25,000 to $40,000 installation cost as part of the home mortgage than to pay power for the life of the mortgage," (Orrin Farnsworth, Intermountain Solar Technologies).

Solar Terms and Technologies

- Photovoltaic (solar cell) systems—convert sunlight directly into electricity. A PV cell is made of semi-conducting material that absorbs the sunlight. The simplest cells power watches and calculators, while more complex systems can light houses and provide power to the electric grid. The solar panels usually hold about 40 PV cells and on a sunny day, panels can make 100watts of electricity per square meter.



- Concentrating solar power systems—sunlight is collected and focused with mirrors to create high-intensity heat which produces steam or power to generate electricity. One key attribute of concentrating solar energy systems is their compatibility with existing power plants. Many of the same technologies are used, the main difference being the substitution of sun power for fossil fuels.

> ***"This evolutionary aspect—as distinguished from revolutionary or disruptive—results in easy integration into today's central station based electric utility grid. It also makes concentrating solar power technologies the most cost-effective solar option for the production of large-scale electricity generation."*** *EREN*

- Solar water heating systems—a flat-plate collector absorbs heat from the sun. An absorber plate heats fluid running through the tubes in the collector. The heated fluid is used to heat and/or provide energy to cool buildings. There are large commercial and industrial buildings that use solar collectors to replace traditional heating/cooling energy sources. A typical system will reduce the need for conventional water heating by about two-thirds.

- Passive solar heating—strategic methods of constructing buildings with south-facing windows and solar absorbing floors, and walls. The building can also use natural sunlight to lighten the interior of the buildings during the daylight hours. Incorporating passive solar designs can reduce heating bills as much as 50 percent. An example of how passive solar heating can be effective are the homes designed by German architect, Ulrich Mueller. These “passive houses” stay warm all through the German winter—without a central heating system. As a result, they use only 10 percent to 20 percent of the energy required by a conventional home. Most of the heat in passive homes is generated from solar energy coming in through the windows, plus the heat generated by occupants and appliances. The homes are built to lose as little heat as possible. Walls are thickly insulated, doors sealed tightly, and windows are triple-glazed. Only when the outside temperatures fall below 23° F. is a backup heater needed.

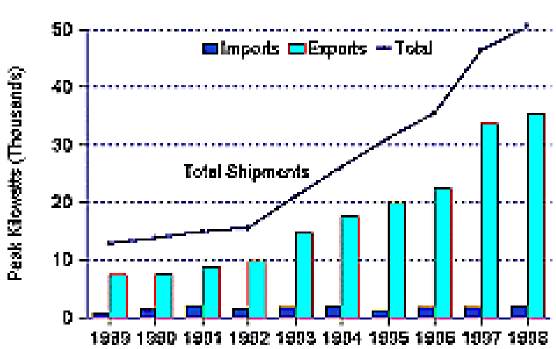
- A 1,400-square-foot, three-bedroom duplex goes for $180,000—about five percent more than a comparable house built to a lower energy-saving standard; however, the cost is made up over time in the form of lower utility bills.

- Kronsberg, Germany is part of a five-nation, 250-unit EU project to test the feasibility of passive houses. Altogether there are now more than 700 such dwellings in Europe, and more are on the way.

- Outside London, British architect Bill Dunster and his partners are building a $17 million residential and commercial complex based on some of the same principles, (Henry Muller, *Fortune*, “Winds of Change”, Monday, March 19, 2001).

- Solar ponds—a combined collection/storage system. Saltwater ponds have a dark, heat-absorbing, brine layer on the pond floor. These ponds are “graded” in the fact that they decrease in salinity as we move from the pond floor to surface. The sun heats the dense brine and the brine holds the heat in place. These ponds can reach boiling temperatures. Solar ponds store heat long after the sun has set, so they are very useful for heating at night. They are inexpensive to build and can cover hundreds of acres and can collect solar energy on a grand scale. The largest prototype we have is that the system on the shores of the Dead Sea in Israel. This is the largest saltwater solar energy system in the world.

Photovoltaic Cell and Module Imports and Exports (1989 to 1998)



Solar energy is especially useful for niche markets…camping, remote houses, cabins, government testing sites,etc. The U.S. Department of Energy predicts the expansion of specialized niche markets in the solar power industry over the next five to ten years. The U.S. Department of Energy also estimates that by 2005, there will be as much as 500 megawatts of installed concentrating solar power systems worldwide.

Annual photovoltaic (PV) cells and modules shipments have increased steadily. Shipments reached 50.6 peak megawatts in 1998, a 9.1-percent increase from1997. Exports totaled 35.5 peak megawatts, representing 70 percent of total shipments as compared to 73 percent in 1997, and imports totaled 1.9 peak megawatts. There were 21 companies that reported PV cell and module shipments.

The U.S. Department of Energy's National Renewable Laboratory (NREL) performed a survey to determine how interested the public would be in using renewable energies if they had to experience a small increase in their utility bills. The report findings were promising as the majority of residential utility customers said that they were willing to pay at least a modest amount more per month on their electric bills for power from renewable sources. Photovoltaic solar systems were among the most favored renewable sources of electricity, (NREL; *Willingness to Pay For Electricity from Renewable Resources: A Review of Utility Market Research*, NREL/TP.550.26148; Golden, CO, July 1999).

Photovoltaic (PV) cells and modules are divided into three categories: (1) crystalline silicon; (2) thin-film, made from photosensitive materials; and (3) concentrator, in which a lens is used to gather sunlight onto the cell or module surface. The following diagram shows what sectors of the market preferred what types of photovoltaic cells and modules and what the end use was for solar component. This information would be valuable to a new wholesaler or distributor targeting the solar energy industry.

Shipments of Photovoltaic Cells and Modules by Market Sector, End Use, and Type
1997 and 1998 (Peak Kilowatts)

Sector and End Use	Crystalline Silicon	Thin-Film Silicon	Concentrator Silicon	Other	1998 Total	1997 Total
Market Sector						
Industrial	12,610	622	0	0	13,232	11,748
Residential	15,247	679	10	0	15,936	10,993
Commercial	7,733	680	48	0	8,460	8,111
Transportation	3,195	245	0	0	3,440	3,574
Utility	3,378	587	0	0	3,965	5,651
Government	2,698	110	0	0	2,808	3,909
Other	2,325	395	0	0	2,720	2,367
Total	**47,186**	**3,318**	**58**	**0**	**50,562**	**46,354**
End Use						
Electricity Generation Grid Interactive	13,392	800	0	0	14,193	8,273
Remote	7,841	783	10	0	8,634	8,630
Communications	7,635	645	0	0	8,280	7,383

Consumer Goods	1,097	101	0	0	1,198	347
Transportation	6,111	245	0	0	6,356	6,705
Water Pumping	4,162	144	0	0	4,306	3,783
Cells/Modules to Manufacturers	4,505	539	0	0	5,044	5,245
Health	1,000	61	0	0	1,061	1,303
Other	1,443	0	48	0	1,491	4,684
Total	**47,186**	**3,318**	**58**	**0**	**50,562**	**46,354**
Energy Information Administration, "Annual Photovoltaic Module/Cell Manufacturers Survey."						

The industrial sector grew 13 percent from 1997 to 1998 and the commercial sector grew four percent. The PV shipments for consumer goods more than tripled in 1998 from 1997, which was probably the result of an increase in recreational vehicle and marine sectors solar applications, two of the fastest growing niche markets. Electricity generation, which consists of both grid-interactive and remote applications, continues to be the predominant end use for PV cells and modules. In 1998, these end uses accounted for 45 percent of total shipments. Shipments for grid-interactive electricity generation alone grew 72 percent in 1998 over 1997, while shipments for communications increased just 12 percent in 1998.

Utah's Solar Resources

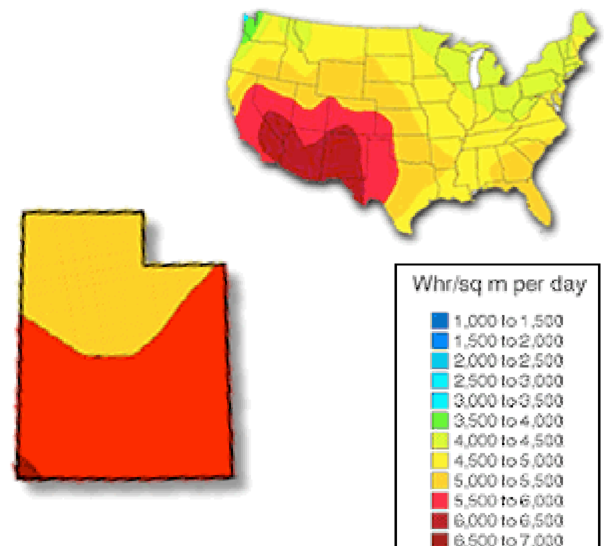
"The sun is almost always shining in Utah…it is a sunny state with lots of potential for growth. Physical features such as our desert climate, high altitude, and inland location make collection of solar rays more efficient and reliable in Utah,"(Rod Hyatt, In Hot Water Heat and Power).

The Denver Regional Office of the U.S. Department of Energy analyzed the solar resources in each state and created charts showing Utah's solar resources. As solar energy varies by location and by time of year, the results shown are yearly averages. The solar resources are expressed in watt-hours per square meter per day (Wh/m^2/day), which is a rough measure of how much energy falls on a square yard over the course of an average day.

Different solar technologies will convert solar energy in different ways. For reference, Utah's solar resources will be expressed in terms of producing electricity. We will look at the two major categories of solar systems—flat plate solar systems and concentrating solar power.

Utah’s flat-plate solar system potential

Flat-plate solar systems are composed of panels that collect sunlight and convert it to either electricity or heat. Because of their simplicity, flat-plate collectors are often used for residential and commercial building applications. They can also be used in large arrays for utility applications. These technologies include photovoltaic (PV) arrays and solar water heaters. This map shows how much solar radiation reaches an installed flat-plate collector. For flat-plate collectors, Utah has very good solar resources throughout most of the state. “Let's say you installed a PV array with a collector area equal to the size of a football field. In one of Utah’s best locations, you would produce around 1,138,000 kilowatt hours per year, enough to power 114.2 average homes,”(DOE, Denver Office).



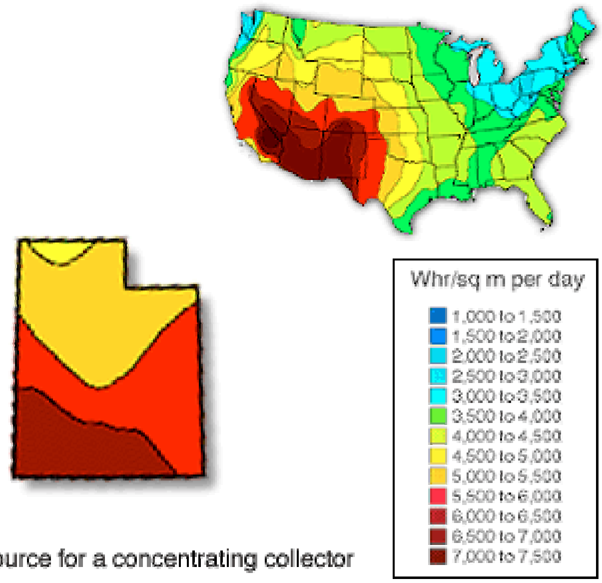
Solar resource for a flat-plate collector

Utah’s solar concentrator potential

Concentrating solar power plants produce electricity by converting the sun’s energy into high-temperature heat using various mirror configurations. The heat is then channelled through a generator. The plants consist of two parts: one that collects solar energy and converts it to heat, and another that converts heat energy to electricity.

Solar concentrators are generally used for large-scale applications such as utility or industrial use. But they can also be used in small-scale applications, including remote power applications. Concentrating solar power systems can be sized for village power (10 kilowatts) or grid-connected applications (up to 100 megawatts). Some systems can be combined with natural gas, and the resulting hybrid power plants provide high-value power. These attributes, along with excellent solar-to-electric conversion efficiencies, make concentrating solar power an attractive renewable energy option.

The solar resource for concentrators varies much more across the United States than the flat-plate solar resource. The map shows that, for concentrating collectors, Utah has good resources throughout the state with the best resources falling in Southern Utah. “How much power would a concentrating system produce? Let's look at a solar electricity system with a collector area of 200,000 square meters — a system that would cover roughly 150 acres. In the state's best areas, this system would produce about 56,122,000 kilowatt hours per year — enough to power 5,632 homes,"(DOE, Denver Office).



Solar resource for a concentrating collector

Utah's competitive advantages in solar production

In addition to having good solar resources, Utah also has some established advantages already in place if they wanted to focus on photovoltaic cell or solar module production. "Utah is in a good position to become a leader in the solar power industry. The technology used to produce solar products and semiconductors is essentially the same. Utah already has strong capabilities in the production of semiconductors," (David Lochtfeld, UofU Dept. of Natural Resources).

The solar industry has grown in Utah. In 1997 there were 15 dealers providing jobs for 25 people. Today, there are 35-50 dealers providing jobs for 100 people. These are great rural jobs as hourly installation wages run $50-$60/hour. Solar energy usage in Utah is generally focused on second or rural homes. There are several niche markets. In addition, there are wealthy urban people who use solar "just for fun".

Recommendations for Solar

USE UTAH'S CAPABILITIES IN THE SEMICONDUCTOR INDUSTRY TO DEVELOP UTAH'S SOLAR POWER INDUSTRY BY COUPLING INDUSTRY WITH RESEARCH INSTITUTIONS, CREATE INCENTIVES TO ENCOURAGE CLEAN ENERGY USAGE, AND HELP TO EDUCATE THE PUBLIC

Steps to Take

- **Facilitate connections between universities and local companies to focus on the development of solar products, using semiconductor and other technologies**

Utility giants, like PacifiCorp, do research in solar technologies. However, it currently isn't profitable enough to rival traditional forms of energy production on a large-scale basis. Therefore, the necessary time and dollars are not spent on solar development.

> ***"Utah is in a good position to become a leader in the solar power industry. The technology used to produce solar products and semiconductors is essentially the same. Utah already has strong capabilities in the production of semiconductors."***
> *David Lochtfeld, UofU Dept. of Natural Resources*

Utah has great research institutions that could help in this dilemma. If there were some joint projects established, backed by federal solar energy funding, Utah could see some real developments. Dr. P. Craig Taylor, Chair of the Physics Department of UofU would be a good "team leader" in a project such as this. He has thoroughly research the photovoltaic technologies.

As was mentioned earlier, Utah has a "leg-up" on solar system development because of their existing stronghold in the semiconductor industry. As there is an excess of demand and limited supply of solar products, this seems like a natural market opportunity for Utah. Micron and Iomega are two companies that would be helpful in photovoltaic research.

NREL's Colorado solar energy lab is the world headquarters for solar energy research. Millard County, of Utah, performs some solar energy research. .

- **Encourage manufacturing, wholesale, and retail growth in the solar industry.**

One outstanding similarity between the professionals we interviewed was the fact that they all mentioned that there is more demand for solar systems than manufacturers, wholesalers, and retailers can handle. Solar power products are being sold as quickly as they are manufactured.

The California energy crisis has spurred a lot of growth in the solar industry. As more consumers experience blackouts and heightened electricity prices, the more people are turning to alternative forms of energy. Solar power is viewed as a fairly stable alternative to the grid. Solar power products are selling as fast as they can be manufactured. This is a growing industry and it is expected that this industry will continue to grow even though it is not the most cost effective or stable form of energy.

In addition, solar energy production is becoming more and more popular in third world countries that do not have an electric grid infrastructure. Solar energy is a good alternative because is can be supplied on a small scale for less than it would cost to develop an all-encompassing grid system. There are huge third-world uses for solar energy powered buildings—Africa and India are big customers.

Dr. Craig Taylor also mentioned that BP Solar, the world leader of solar panel production, was thinking of establishing their business in Utah a few years ago. However, they located elsewhere because there were no immediate economic incentives to locate here. Currently, the only solar wholesaler in the state is Orrin Farnsworth, of Intermountain Solar Technologies. He is a registered wholesaler for BP Solar.

Intermountain Solar Technologies is expanding as rapidly as it can and it is about 1000 solar panel modules behind right now. There is huge opportunity for growth in this field right now...the company has grown no less than 30% annually.

Orrin did $1 million in business in Utah last year ($2 million dollar market in Utah). This year, he projects to do $1.75 million in business in Utah ($3.5 million dollar market in Utah). It is projected that Utah become a $10 million/year market in the next five years.

"Utah's competitive advantage of 'wide open spaces' should be used for solar farms in southern Utah. As stated by Scott Skylar, former chairman of the National Solar Energy Industry Association, '150 square miles of Utah sun would be enough to provide power for the whole country.'" *Orrin Farnsworth, Intermountain Solar Technologies*

Orrin mentioned that given the current solar technology, photovoltaic production would be better done outside of Utah; however, there is room for growth in the wholesaling and retailing/contracting side of the business and room for growth in the R&D side of photovoltaics. Essentially, if Utah was to position themselves as a leader in cutting-edge photovoltaic technology, then the solar production plants would naturally want to locate here. Solar production economies of scale aren't possible now because the industry is not developed enough in Utah. If Utah wanted to become a solar power capital, mass production of components and systems is a possible avenue for development.

- **Market solar energy! For example, help local solar businesses with the Solar Parade of Homes.**

The state government should help in "advertising" solar energy and other forms of alternative energy. The "Solar Parade of Homes" is a good example of an activity that could be an alternative marketing opportunity. The more Utah residents hear about alternative energy uses, the more potential increase in the demand for clean energy.

Another way to look at solar energy is to realize that it is a supporting industry for telecommunications, because of the off-grid locations that telecommunications demand, and for that matter, a supporting industry for any company that needs energy in remote sites.

The public is not aware enough to have a need for solar products in Utah. We could take a "pull strategy" of marketing outside of Utah, but would have to employ a "push strategy" inside of Utah. A barrier could be overcome as this changes and as companies become aware of the business that is done with states surrounding Utah.

> ***"There was a lot of solar business spurred by the pre-Y2K worries. This year is 'Y2K with a reason'...the California energy crisis has sparked a lot of business…I speak daily with people who have $500-$1000 monthly energy bill."*** *Orrin Farnsworth, Intermountain Solar Technologies*

- **Make incentives—by passing an alternative energy tax credit or net metering bill—to make it attractive to businesses and residents to use clean energy.**

California has incentives in place to encourage alternative energy uses. They have a $3/watt matching policy, which equals out to be the cost of one-third to one-half of a solar system. California has an additional $100 million in energy funding this year dedicated to alternative forms of "clean energy", so the matching policy will probably be increased to $4.50/watt, which covers about 50 percent of the cost of the solar system. There are also incentives in place to encourage people to send energy back to the power companies and having their meter run backwards.

Germany and Japan are big alternative energy markets. The governments subsidize about 50 percent of solar installation costs. Germany has a four times the market value metering policy. New Zealand has a seven times net metering policy to encourage selling energy back to the power companies.

A net metering bill for the legislative special session is being considered, which would make it possible and profitable to sell power back to the power companies during peak energy usage hours. Thirty-one states already have a net-metering bill in place. The projected increase in new business employment will double in the next 18 months if this bill is passed. Marty Stevens is chartering the bill right now.

- **Help to educate the public on efficient ways to conserve.**

Educating the public is a necessity—but this may have to be accomplished by incentives, such as higher energy costs so there is a natural interest in alternative energy.

There are many steps in appliances and lighting that can be taken to make a home more energy efficient—natural gas and evaporative cooling refrigeration mechanisms. The solar installation costs are cut to $25,000 if an energy efficient home is built.

"Bigger is not always better, successful formation of solar energy hubs or natural gas-powered turbines would be a great alternative to the huge power plants that we have now."
Rod Hyatt, In Hot Water Heat and Power

Education of the public is a priority for increasing demand. The state could sponsor community courses or meetings where people are taught how to read their energy bills, and where citizens receive education about the real costs (loss of independence, reliability) of grid power. The state could also require simpler bills or send educational pamphlets out with billing statements.

"We are missing the consumer demand in Utah. Utah residents are used to having energy all of the time and have never had to worry about conservation…There will have to be blackouts or increases in price to encourage people to change their practice,"(Rod Hyatt, In Hot Water Heat and Power).

Not only is consumer demand lacking, but consumers are not aware of the benefits of alternate energy. They do not know they can actually save money by going solar. Consumers do not know that by staying attached to the grid and simultaneously running a home solar system, they could actually sell their excess electricity to the public utility. The demand for "efficient homes" is fairly small in Utah and is much greater in California

- **Determine what the barrier is to receiving 50 million in federal funding for a solar-powered cosmic ray testing site in the western Utah desert**.

There may be a huge potential opportunity for a solar-powered cosmic ray testing site in the Utah west desert. 50 million in funding from the federal government was approved a couple years ago; however, the funding didn't go through and the U of U is working on receiving the grant right now, (Orrin Farnsworth, Intermountain Solar Technologies). Receiving that grant would promote the solar industry in Utah.

- **Examine the possibility of developing solar pools with the brine-rich saltwater in the Great Salt Lake.**

  Dr. Clair Batty, Utah State University, has performed extensive research on producing hotter than boiling waters in solar ponds. In order to use the Great Salt Lake, there would need to be reservoirs made to prevent waves from disturbing the process.

  The Dead Sea is comparable to the Great Salt Lake and their saltwater energy projects have been very successful. Dr. Batty visited the Dead Sea and spoke to experts there on how to develop a like project here in Utah. He has also had successful saltwater solar ponds in Logan that have produced boiling temperatures year-round and made greenhouse horticulture possible.

  It is too expensive to create thermal energy from these temperatures; however, there are excellent process heat applications for “curing” products, food processing, year-round greenhouses, and drying heat.

  Dr. Batty would be very helpful if the state decided to pursue saltwater energy projects.

Costs of Solar

Concentrating solar power technologies currently offer the lowest-cost solar electricity for large-scale power generation of 10 megawatts and above. Current technologies cost $2-$3 per watt. This results in a cost of solar power of $.09-.12 per kilowatt-hour.

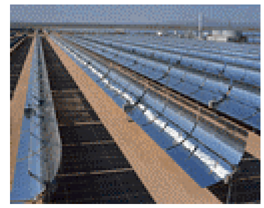
New hybrid systems that combine large concentrating solar power plants with conventional natural gas combined cycle or coal plants can reduce costs to $1.5 per watt and drive the cost of solar power to below $.08 per kilowatt-hour.

Advancements in the use of low-cost thermal storage will allow future concentrating solar power plants to operate for more hours during the day and shift solar power generation to evening hours. Future advances are expected to allow solar power to be generated for 4¢-5¢ per kilowatt-hour in the next few decades. (Energy Efficiency and Renewable Energy Network, www.eren.doe.gov/state_energy).

For solar home systems, the up-front costs are expensive, around $35,000 a system for a five-bedroom home; including panels, generators, and batteries. After initial investment in a solar system, the savings in energy bills will offset the entire cost of most systems in an average of seven years, so solar energy will be cost-prohibitive for a short-term homeowner. Considering that the average homeowner lives in a home for seven years, the savings on energy are enough to make rational consumers just indifferent.

However, for many rural homeowners, the up-front costs of "hooking-up" to public power lines (the grid) are more than to develop a self-sustaining solar system. Therefore, rural homeowners will see an immediate return on their investment, (Rod Hyatt, In Hot Water Heat and Power).

Solar Environmental Issues



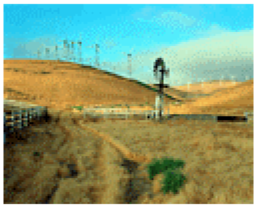
Solar energy is a very clean "green power". There are essentially no emissions produced. It also works to lower overall pollution and lessen the greenhouse effect.

Solar Expert Contacts

- Dr. P. Craig Taylor ; Chair, UofU Physics Department ; 801-581-8751 (interviewed and attended the energy summit)
- Orrin Farnsworth, Intermountain Solar Technologies (privately owned S-corp), Chairman of the Utah Solar Energy Industry Association, wholesaler for BP Solar, 801-501-9353. He is the only wholesaler in the state and his company experienced outstanding growth these last few years. He has worked with the legislature to get the alternative energy tax bill resubmitted (House Bill 334) after expired on Dec. 31st of last year. Orrin is also involved with the Smiles of Ghana project (group of dentists, doctors, and alternative energy experts—supplies the solar panels to build solar energized buildings and pumps.
- NREL's Solar Energy Lab in Colorado (headquarters for the national solar energy lab.
- Millard County is the center for some solar research.
- United Solar Systems are the largest Silicon Plant and are located in Troy, Michigan
- Rod Hyatt, Owner of In Hot Water Heat and Power**,** Involved with the Solar Parade of Homes last year, 801-745-2009 (largest solar dealer in the state, constructs energy efficient homes)
- Dr. Clair Batty, Dept. Head, Utah State University. He performed extensive research on thermal energy and heat captured in saltwater. The Great Salt Lake could be a great resource for the technology. (interviewed)

Wind

There are many applications for wind-fueled turbines; wind power is used for generating electricity, charging batteries, grinding grain, and pumping water. There are many rural as well as residential applications for wind power. "Large, modern wind turbines operate together in wind farms to produce electricity for utilities. Small turbines are used by homeowners and remote villages to help meet energy needs…modern wind turbines are divided into two major categories: horizontal axis turbines and vertical axis turbines. In addition, old-fashioned windmills are still seen in many rural areas," (www.eren.doe.gov). Large wind farms are used to provide electricity to the power grid, which is then sent to businesses and homeowners, essentially anyone who is connected to the grid.



The quality and efficiency of wind energy is especially high in the Midwest and Great Plains, as the wind blows almost continually in certain areas. However, there are many other areas in the U.S. where wind is a viable resource. For example, there are many successful wind farms in California.

Utah's Wind Resources

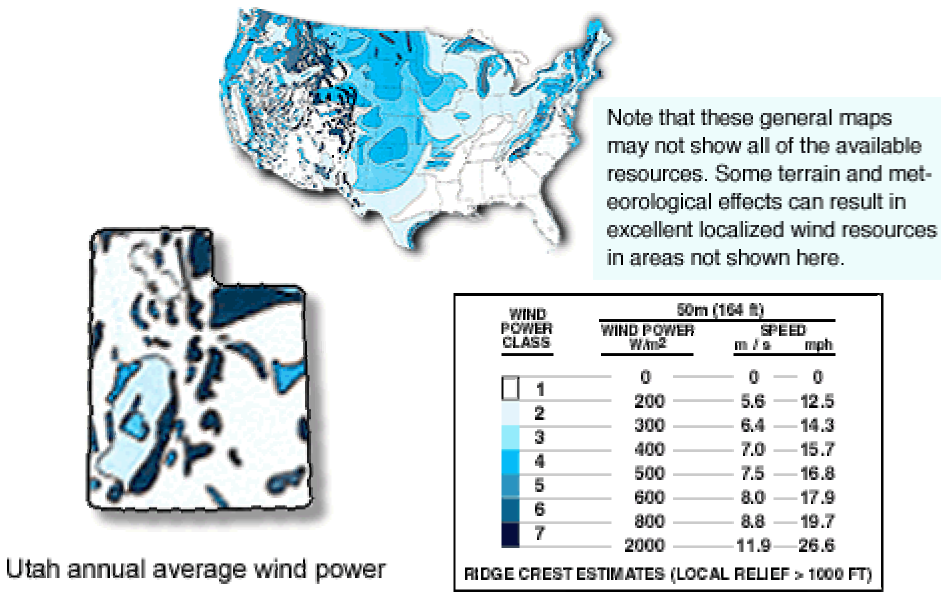
"If all the State's wind energy potential was developed with utility-scale wind turbines, the power produced each year would equal 171 percent of the entire state's electricity consumption", (Energy Information Association, www.eia.doe.gov).

As a renewable resource, wind is classified based on typical wind speeds. These classes range from Class One (the lowest) to Class Seven (the highest). In general, Class Three winds and above can be used for generating power with large, utility-scale turbines. Smaller turbines can be used with any wind class. Class Four and above are considered good wind resources.

> ***"If all this wind potential was developed with utility-scale wind turbines, the power produced each year would equal 34,000,000 megawatt-hours, or 171 percent of Utah's current electricity consumption."*** *DOE, Denver Regional Office*

In certain areas, as the map below illustrates, Utah has excellent wind resources. According to the Denver Regional Office of the Department of Energy, the potential of wind power in Utah is great.

First, let's look at the land which has a wind power class of 3 or higher-the usable resources. Next, let's not count land with urban development or land that is environmentally sensitive. There may be other land-use conflicts as well, so we subtract out 50 percent of forest land, 30 percent of farmland, and ten percent of rangeland. This results in about one percent of the state of Utah having good winds and being available for development. Of note, a wind farm uses only a small portion of the land, so the actual percentage of state land covered would be about 0.1 percent. If all this wind potential was developed with utility-scale wind turbines, the power produced each year would equal 34,000,000 megawatt-hours, or 171 percent of Utah’s current electricity consumption.



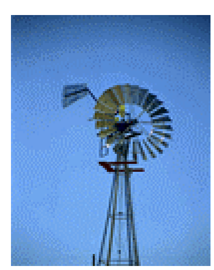
Department of Energy, Denver Regional Office

There are currently two wind generators operating in Utah, and Energy Services is currently operating one of them in a research partnership. There is a test site in Spanish Fork and The Camp Williams wind turbine can be seen from I-15 near the point of the mountain.

When the Department of Energy offered anemometers to the public to measure wind resources, the public response was overwhelming. They had 200 calls and 51 applications and could only select fifteen. There is a very high interest in windpower in Utah.

Recommendations for Windpower

THIS IS A HIGH-PRIORITY ENERGY RECOMMENDATION: EMPLOY THE NATIONAL RENEWABLE ENERGY LABORATORY TO COMPLETE A RECENT SURVEY ON WIND RESOURCES IN UTAH AND DEVELOP SOME WIND TURBINES IN KEY LOCATIONS



- **Employ the NREL to perform an up-to-date wind survey with modern technologies.**

  A survey done by the NREL would cost $150,000 and it would be very beneficial to the state. Knowing where a high wind resource may exist is valuable to a wind energy project developer or potential wind energy user because it allows them to choose a general area of estimated high wind for more detailed examination. NREL identifies and gathers data for wind resource maps of the United States and foreign countries. These maps help developers or users find areas worthy of detailed wind resource monitoring.

Utah has extensive opportunities for development of wind technology, and the Utah Department of Energy already has an advanced wind study that they are currently working on. Christine Watson is heading the wind study. She has visited Colorado and other places to determine how best to develop the industry here.

Christine frequently receives phone calls from businesses who want to product power on-site. Micron called her a couple of weeks ago concerning setting up a wind system at their location.

Also, she has spoken to Indians from the Gosh Ute Tribe about developing windpower on their land. An Indian by the name of Sammy Blackbear is interested in developing the technology on their land. It is an excellent site for wind-powered generation.

- **"Build it and they will come."**

Christine Watson, after analyzing the success of the wind industry in other locations, determined that as we show developers and manufacturers that the wind is here to harvest in Utah, they will come to Utah with their business.

The future of wind technology in Utah is in mid-sized wind generators, since Utah's gusts can destroy very large wind generators.

- **Be involved in the Wind Conference in October and the Industries of the Future Showcase in August.**

These events are bringing industry leaders and associations together, like NREL from all over. They are excellent ways to exchange information, make industry connections, and further a technology.

Christine Watson has contact information for these conferences.

Costs of Windpower

The cost of energy from the wind has dropped by 85 percent during the last 20 years. Incentives like the federal production tax credit and net metering provisions available in some areas improve the economics of wind energy.

Windpower currently costs four cents a kilowatt-hour, but is nearing three cents with increases in turbine technology. A 750-kilowatt turbine, taking up a half an acre of land, costs $750,000.00 to install. It is a one-time sunk cost.

Wind Environmental Issues

Wind energy is considered a green power technology because it has only minor impacts on the environment. Wind energy plants produce no air pollutants or greenhouse gases. However, there are some minor concerns of birds that get caught in the turbines.

Wind Contacts

> ***"To brand Utah effectively, we need to be proactive to reacting to potential energy situations…local power production currently satifies the Utah need…Utah could be positioned as an energy-efficient state which would be helpful in attracting business here."*** *Orrin Farnsworth, Intermountain Solar Technologies*

- Christine Watson, State of Utah, Office of Energy, ChristineWats@aol.com, 801- 538-4792 (interviewed)
- Dean Davis, 801-798-8784 (referred by Christine Watson)
- Gary Tassainer, Tasco Engineering, 801-766-9500 (referred by Christine Watson)
- Dr. Craig Hansen, 801-278-7852, (referred by Christine Watson)
- John Allred, State of Utah, Office of Energy, "Showcase of the Industries of the Future (August 25)", (referred by Christine Watson)
- The Danish Wind Turbine Manufactures Association: www.windpower.dk
- The Danish Owners Association; www.danmarks-vindmoelleforening.dk
- Risø National Laboratory: www.risoe.dk
- Energy and Enviromental Data: www.emd.dk
- The Danish Ministry of Environment and Energy. www.mem.dk
- EWEA - European Wind Energy Association. www.ewea.org
- BWEA - British Wind Energy Association. www.bwea.com

Branding Utah as a "High-Tech Oasis"

Utah needs to be proactive in efficient energy production to attract businesses here. Power is too expensive for many companies in California to stay solvent. The California situation provides an opportunity to us. Utah should create industries with non-polluting impact and provide power for excesses in demand.

California businesses shut down because the increase in power costs. Orrin Farnsworth, Intermountain Solar Technologies, has spoken with several companies whose energy bills have double (from $50,000 to $100,000). This is too much for businesses to handle because for many companies this nullifies their profit margin. In addition, many people on fixed incomes can't afford to keep their "dream homes".

Utah has traditionally been viewed as environmentally backward, and known for being rather slow in implementing environmental regulations. Also, air quality on the Wasatch front is very poor. We do not have a good environmental reputation.

In terms of tourism and business location, Utah could really improve its image. If we were in the process of doing something about air quality or greener power generation during the Olympics, we could really improve our environmental reputation and we could market Utah as an environmental and alternative energy leader. Utah could stand out as a "High-Tech Oasis" in the desert.

Renewable Energy Industry Overview

Companies

As we have performed our research, it has become apparent that for industry analysis purposed, there is no "renewable energy industry" per se; however, after further investigation, it become obvious that renewable energy is placed in the Utilities-Alternative Energy Sources category, which is basically made up of renewable energies. These companies research, develop, and supply alternative sources of energy by using biomass, solar, hydroelectric, geothermal and wind, as well as nuclear technologies. For our purposes, I have included just the renewables that could be expanded in Utah; in other words, I have excluded nuclear power from our list. The following information was found on Hoovers Online, www.hoovers.com and on the companies' personal websites.

- **AAA Solar Service and Supply**

2021 Zearing Ave. NW		Phone:	505-243-3212
Albuquerque, NM 87104		Fax:	505-243-0885
Website:	www.aaasolar.com		

Company Type:	Private
Key Business:	Solar Electricity, Wind Turbines, Solar Water Heaters, Home Heating Systems, Solar Swimming Pool Heaters, Solar Ovens
Key People:	CEO, Jeff Schmitt

AAA Solar has distributed over 10,000 solar and wind energy systems over the 22 years that they have been in business. They distribute a full line of alternative energy products including solar electric systems, wind turbines, solar hot water heaters, solar home heating systems, swimming pool heating systems and solar ovens. Many systems are available in kit form for the do-it-yourselfer. They install and service solar systems and high efficiency appliances throughout New Mexico and neighboring states.

- **Amonix Incorporated**

3425 Fujita Street		Phone: 310-325-8091
Torrance, California 90505		Fax: 310-325-0771
Website:	www.Amonix.com	

Company Type:	Private
Key Business:	High-concentration photovoltaic systems (HCPV) and solar-powered generating systems
Contact:	Eric Dominguez, Director; 310-325-8091

Amonix Incorporated is the world leader in high-concentration photovoltaic (HCPV) systems as well as the selected supplier for the world's largest HCPV installation in Glendale, AZ. Arizona Public Service Co. (APS), Arizona's longest-serving electric utility, plans to install the world's largest HCPV solar project using Amonix's patented photovoltaic cell technology.

The distributed, multi-site system will produce more than 500 kilowatts and will produce enough energy to power more than 165 homes, and is expected to generated over 1,000 megawatt hours per year when fully operational. With conversion efficiency exceeding 17 percent, Amonix's solar array is projected to be the lowest-cost photovoltaic technology when manufactured in volume.

The energy will be fed into APS's power grid, and will replace the equivalent amount of electricity that would have ordinarily been generated by more traditional, polluting methods.

- **AstroPower, Inc.**

Solar Park 461 Wyoming Rd.		Phone: 302-366-0400
Newark, DE 19716-2000		Fax: 302-368-6474
Website:	www.astropower.com	

Company Type:	Public
Key Business:	Solar cells and modules
Key People:	President, CEO, and Director; Allen M. Barnett SVP, CFO, and Secretary; Thomas J. Stiner SVP Marketing and Sales; Peter C. Aschenbrenner VP International Sales, Salama Nagib
Contact:	Marketing Comm.; Michael Wright 302-366-0400 Ext. 195
Stock :	NASDAQ: APWR

Financials: 2000 Sales (mil.): $49.8
1-Yr. Sales Growth: 43.9%
2000 Net Inc. (mil.): $3.5
1-Yr. Net Inc. Growth: 52.2%
2000 Employees: 330
1-Yr. Employee Growth: (5.7%)

AstroPower, one of the fastest growing solar power companies, produces the world's largest photovoltaic cells, modules, panels, and SunChoice systems used for converting sunlight into electricity. AstroPower and GPU recently announced that their solar electric power plant in Hopland, CA exceeded expectations for annual output during its first year of operation. The 132-kilowatt plant is owned and operated by GPU Solar, a joint venture of AstroPower, Inc. and GPU Diversified Holdings.

> **"In the current energy crisis in California, marked by energy shortages and volatile pricing, clean power from the GPU Solar plant at Hopland offers consumers a steady, dependable source of electricity at a fixed cost."** James Torpey, President, GPU Solar

AstroPower's proprietary silicon-film process allows continuous production of silicon sheets and can make cells virtually any size. The company sells its products to equipment manufacturers, distributors, and residential and commercial end-users; European sales account for more than half of revenues.

AstroPower is in two joint ventures: one with electric utility GPU International to market wholesale solar power and another with Atersa in Spain to provide module assembly services.

Their "Solar 2000" was the first grid-connected solar power plant built exclusively to meet the needs of California's deregulated electricity market and is located in Hopland, CA. The 15,000-square-foot plant generated more than 163,000 kilowatt-hours in its first year of operation. "That's 7% above our predictions for the year, so we could not be happier with the plant's performance," said AstroPower Vice President, Howard Wenger. "This plant is one more example of how solar power delivers energy price stability and does so with zero pollution."
.
Rankings:

- S&P Small Cap 600, December 2000
- 39th on Business Week's Top 50, February 2001
- S&P Small Cap Company List for 1 and 3-year performance

- **Bonus Energy A/S**

BONUS Energy A/S
Fabriksvej 4 - DK-7330 Brande
Denmark

Phone: 45-9942-2222
Fax: 45-9718-3086

Website: www.bonusenergy.com

Company Type:	Private
Key Business:	Wind turbines
Financials:	2000 sales (DKK'000): 1,822,196 2000 net income (DKK'000): 95,077

Danish company, Bonus Energy A/S recently announced the conclusion of a deal to construct one of the world's largest wind power facilities which will be located on King Mountain in West Texas, USA. The Project will consists of 214 wind turbines and will have a capacity of 278.2 megawatts, sufficient to supply power to over 139,000 Texas homes and to save, over its 20 year life, the emission of nearly 20 million tons of carbon dioxide.

> ***"The order for the King Mountain Project is the largest order in Bonus' history, and it marks a new breakthrough for Bonus on the US-market", says Palle Norgaard, Managing Director of BONUS Energy A/S. He adds, "With this considerable order we have secured quite a lot of jobs, not only in our local community but at a number of sub-suppliers' in Europe and the USA as well."***

The project has been developed by Renewable Energy Systems Ltd (RES) together with Cielo Wind Power, LLC, of Texas. RES will build the wind farm and Bonus Energy A/S will supply the 214 wind turbines. The King Mountain wind farm will be fully operational before the end of 2001.

During the 1980s, the Company erected around 1100 BONUS wind turbines in California. For some years, however, Bonus has concentrated on the European markets.

BONUS Energy A/S has carried out development, sale, installation, and maintenance of wind turbines since 1979. Today more than 4,000 BONUS wind turbines are in operation worldwide.

Following is list of companies in the U.S. that Bonus Energy has provided wind turbines for:

- Oak Creek Energy Systems
- The Arbutus Corp/Pajuela Peak Wind Farm
- Windland, Inc.
- American Diversified
- Capital Corp.
- Fayette Manufacturing Corp.
- Flowind/Difko
- Energy Unlimited Inc.
- San Gorgonio Farms
- Whitewater Energy Corp.
- Aeroturbine Energy Corp.
- Windustries

- Northern States Power

- **BP Solar**

BP p.l.c (parent company)

Brittanic House, 1 Finsbury Circus
London EC2M7BA, United Kingdom
Website: www.bp.com

Phone: 44-20-7496-4000
Fax: 44-20-7496-4630

Company Type: Subsidiary of BP p.l.c.
Key Business: Oil and gas; has many subsidiaries in other industries
Key People: Chairman, Peter D. Sutherland
Group Chief Executive and Director, John P. Browne
CFO and Director, John G.S. Buchanan

Stock: NYSE: BP
Financials: 2000 Sales (mil.): $148,062
1-Yr. Sales Growth: 77.2%
2000 Net Inc. (mil.): $11,870
1-Yr. Net Inc. Growth: 153.3%
2000 Employees: 107,200
1-Yr. Employee Growth: 33.3%

BP, formerly BP Amoco, is the world's #3 integrated oil company, behind Exxon Mobil and Royal Dutch/Shell. It is the largest US oil and gas producer and is also a top oil refiner, and specialty chemicals manufacturer. BP operates 29,000 gas stations worldwide.

BP's gas stations are revolutionary in the fact that it is powered by solar energy. The pumps have a "Space Age" design with touchscreens that allow you to order snacks available inside the store. The see-through island coverings are made of photovoltaic thin film that absorbs sunlight and turns it into electricity. There are more than 200 such stations in ten different countries.

BP Solar had revenues last year of $190 million; in 1999, by contrast, BP saw turnover of more than $100 billion and profits of $5 billion. Nevertheless, BP Solar is one of the world leaders in the manufacture of photovoltaic panels, and its parent is the largest private-sector consumer of solar energy.

Thin film photovoltaic technology consists of semiconductor circuits no thicker than a hair that are deposited directly on glass. Conventional crystalline solar panels are expensive, bulky, and ugly, which is why the most effective uses of solar have been in locations where there's no electricity grid, such as on remote farms or mountain huts, on yachts or buoys, on road signs or telecommunications equipment. Per square foot, thin film is only 50 percent to 70 percent as efficient as crystalline panels. But it is less expensive to produce and looks like darkened glass. BP is in the process of developing thin film in various shades and textures to make them appealing to consumers.

Atul Arya, CFO of BP Solar, concedes that the division did not make a profit last year, and investment plans make it unlikely that it will do so for at least the next three to five years. The goal is to reach sales of $1 billion by 2007. “We see this as a real business,” says Arya. “We'll still be a small part of BP, but we'll be a major player in the solar industry,”(Henry Muller; *Fortune*, “Here Comes the Sun”; Monday, March 19, 2001).

- **Calpine**

50 W. San Fernando St.
San Jose, CA 95113
Website: www.calpine.com

Phone: 408-995-5115
Fax: 408-995-0505

Company Type:	Public
Key Business:	Independent power producer—geothermal, natural gas-fired
Key People:	Chairman, President, and CEO; Peter Cartwright SVP and Chief Information Officer, Dennis Fishback
Contact:	V.P. of Strategy, Dr. Kenneth D. Cory (present at the Utah energy summit); 408-995-5115
Stock :	NYSE: CPN
Financials:	2000 Sales (mil.): $2,282.8 1-Yr. Sales Growth: 169.3% 2000 Net Inc. (mil.): $325.9 1-Yr. Net Inc. Growth: 243.1% 2000 Employees: 1,883 1-Yr. Employee Growth: 117.7%

Calpine, an independent power producer, is the top US geothermal producer; it owns 19 power plants at the largest geothermal facilities in the U.S. and has 850 MW of generating capacity from these plants. Natural gas is the company's main power source: Calpine controls about 5,000 MW of generating capacity through its interests in gas-fired power plants in the US and Canada, and has 14,000 MW under construction.

The firm markets energy to utilities, wholesalers, and end-users. In addition, the company has about 1.7 trillion cubic fett of natural gas reserves. With the acquisition of Encal Energy in 2001, Calpine more than doubled its gas reserves.

- **Energy Photovoltaics**

276 Baker’s Basin Rd.
Lawerenceville, NJ 08648

Phone: 609-587-3000
Fax: 609-587-5355

Website: www.epv.net

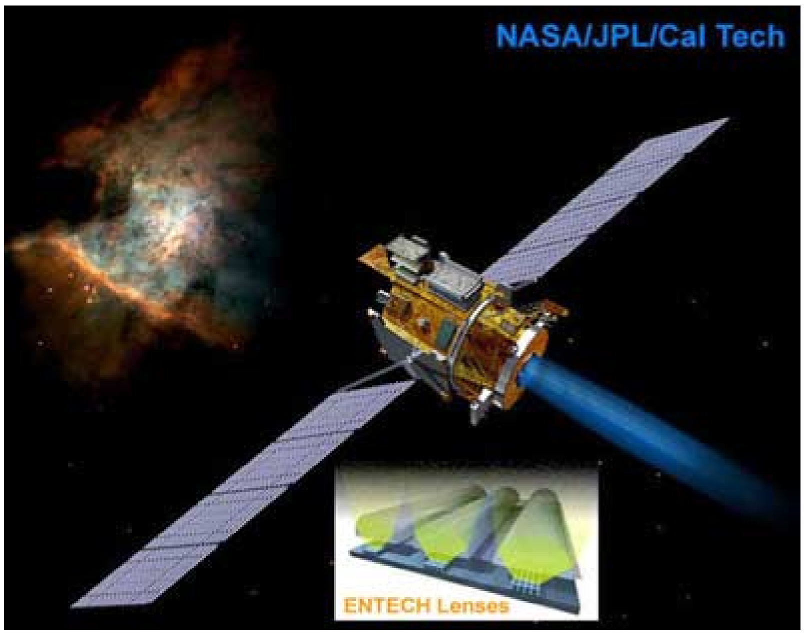
Company Type: Private
Key Business: Thin-film photovoltaic systems
Key People: President and CEO, Zoltan Kiss

Energy Photovoltaics, Inc. (EPV) develops, commercializes, and markets proprietary thin-film photovoltaic (PV) technologies and systems to manufacture PV modules. EPV focuses on the research and development of PV materials and manufacturing processes using amorphous silicon and a more advanced thin-film technology that uses copper/indium/gallium/diselenide materials.

In December 2000, EPV received a $14 million equity infusion from an investor group that acquired a controlling interest in EPV. The group consists of CHI Energy, Inc. of Stamford, Connecticut (a subsidiary of Enel); Integrated Electrical Services, Inc. of Houston, Texas; and MVV Energie AG of Mannheim, Germany. EPV is using the investment proceeds to commercialize its latest thin-film PV module manufacturing processes, expand its marketing and sales activities, and enhance its research and development program.

EPV's existing scientific and technical expertise, international business development experience, recent cash infusion, and expert guidance provided by an enhanced Board of Directors has positioned EPV to become a world leader in the most advanced and cost-effective thin-film PV technologies.

- **ENTECH, Inc.**



1077 Chisolm Trail
Phone: 817-379-0100
Keller, TX 76248
Fax: 817-379-0300
Website:
www.entechsolar.com

Company Type: Private
Key Business: Solar
Key People: CEO, Walter Hesse
President, Mark O'Neill
VP, Marketing; Bob Walters
Contact:
marketing@entechsolar.com

ENTECH provides advanced solar energy technology for a range of technologies ranging from daylighting systems for commercial buildings to solar power arrays for spacecraft. Their patented solar power systems produce electricity from sunlight for both ground-based (terrestrial) and space-based (satellite) applications. Inexpensive Fresnel lenses capture the sunlight, and focus it onto small solar cells, thereby reducing electricity costs compared to conventional flat-plate (planar) solar energy approaches.

ENTECH is working with an outstanding team of NASA, industry, and university organizations to develop a next-generation solar array for space power applications. This new array is called the Stretched Lens Array (SLA) has been tested at NASA Glenn with unprecedented performance for a space solar array of any kind:

- 27.4 percent solar-to-electric conversion efficiency
- 375 W/square miles aerial power
- 378 W/kg specific power

- **Evergreen Solar**

ENTECH Lenses Focus Sunlight on 2.5 kW Deep Space One "SCARLET" Solar Array

211 2nd Ave.
Phone: 781-890-7117
Waltham, MA 02451
Fax: 781-890-7141
Website: www.evergreensolar.com

Company Type:	Public
Key Business:	Solar
Key People:	Chairman, Robert W. Shaw Jr.
	President, CEO, and Director; Mark A. Farber
	VP, Marketing and Sales; Rex A. D'Agostino
Stock:	NASDAQ: ESLR
Financials:	2000 Sales (mil.): $2.2
	1-Yr. Sales Growth: (4.3%)
	2000 Net Inc. (mil.): ($5.2)
	2000 Employees: 74
	1-Yr. Employee Growth: 48.0%

Evergreen Solar, using its proprietary crystalline technology (called "String Ribbon"), the company develops and manufactures solar power cells and panels. Applications for Evergreen's solar cells and systems include highway call boxes, microwave stations, street and billboard lighting, and off-grid rural electrification. Once a novelty, solar power has become more efficient and is now targeted at both remote rural users and the clean-energy set. Evergreen has a distribution and marketing relationship with Kawasaki for the Japanese market.

- **GeothermEx, Inc.**

5221 Central Ave., Suite 201
Richmond, CA 94804-5829 USA
www.geothermex.com

Phone: 510-527-9876
Fax: 510-527-8164

Company Type:	Private
Key Business:	Geothermal consulting, drilling projects
Contact:	mw@geothermex.com or geothermex@compuserve.com

GeothermEx provides consulting, operational and training services in the exploration, development, management, assessment and valuation of geothermal energy. In business since 1973, GeothermEx is the largest and most experienced geothermal energy consulting company in the western hemisphere. They design and direct geological and geophysical exploration projects and shallow and deep drilling projects. They assess geothermal energy resources and help to design and start-up geothermal production systems. They perform hot spring surveys, volcanic risk analyses, and heat flow surveys. Their financial services include project risk analyses, cost and revenue projections and due-diligence for financing. Their experience covers the entire industry, from low-temperature direct-use to high-temperature electric-grade resources, and evaluation of hot dry rock and enhanced geothermal systems projects.

The staff consists of specialists in geosciences (geology, geochemistry, geophysics, hydrology), engineering (drilling, well testing, reservoir, production, power plant, chemical), computer science and economic analysis. All technical staff members have advanced degrees and lengthy geothermal experience (average 15 years), with several members having more than 25 years in the geothermal industry.

GeothermEx has participated in nearly US$ 7,000,000,000 of private financing for the geothermal industry and have had more than 800 projects in 43 countries, on time and under budget.

During the past year, GeothermEx has undertaken several innovative new projects related to drilling, resource evaluation, optimization and planning:

- World Geothermal Congress 2000: technical papers submitted on 15 different topics covering recent GeothermEx work in 9 countries
- Cerro Prieto, Mexico: a hydrogeological model and numerical simulation of the world's largest water-dominated reservoir
- The Geysers (California), U.S.A.: field-wide "coupled" numerical simulation of the world’s largest steam reservoir. A unique example of coupled modeling of the steam delivery system, wells and reservoir that will be used as a practical tool for optimizing power generation

- **GPU Solar**

GPU Diversified Holdings (one of the parent companies; AstroPower, the other parent company has been highlighted previously)

300 Madison Ave.		Phone: 973-401-8200
Morristown, NJ 07962-1911		Fax: 973-455-8377
Website:	www.gpu.com	

Company Type:	Joint Venture Subsidiary of GPU Diversified Holdings and AstroPower, Inc.
Key Business:	Energy; has many subsidiaries in various industries—solar, fuel cells, construction, telecommunications, power marketing, fiber-optics, and mechanical contracting services
Key People:	Chairman, President, and CEO, GPU and GPU Service; Chairman, GPU Capital, GPU Electric, GPU Energy, GPU Nuclear, MYR Group, and Saxton Nuclear; President and CEO, GPU Diversified Holdings: Fred D. Hafer
Contact:	Business Manager of GPU Solar, Eva Gardow, 973-401-8347
Stock:	NYSE: GPU
Financials:	2000 Sales (mil.): $5,196 1-Yr. Sales Growth: 9.2% 2000 Net Inc. (mil.): $234 1-Yr. Net Inc. Growth: (49.1%)

GPU Solar is a developer, owner, and operator of several solar electric power plants in the U.St. The size of the plants ranges from 100 kilowatts to1 megawatt. The first plant developed was "Solar 2000 – Mendocino", a 100kW plant located in California. A second, called Green Mountain Solar Berkeley, was recently completed and is projected to supply 135,000 kilowatt-hours of energy into the California grid this year. Other sites are under development in Pennsylvania, New Jersey, New York and California. The Hopland, CA solar plant, as discussed in the "AstroPower" company description, produced 163,000 kilowatt-hours in its first year of operation.

GPU Diversified Holdings is moving into other non-regulated businesses, including power marketing, alternative energy, construction, and telecommunications. It has acquired MYR Group, which provides electrical and mechanical contracting services, and has invested in a fiber-optic network in the eastern U.S.

Rankings:

- #338 in Fortune 500
- #433 in Hoover's 500
- S&P 500

- **High Plains Corporation**

O.W. Garvey Bldg.
200 W. Douglas, Ste. 820
Wichita, KS 67202
Phone: 316-269-4310
Fax: 316-269-4008
Website: www.highplainscorp.com

Company Type: Public
Key Business: Ethanol production
Key People: Chairman, Donald D. Schroeder
President and CEO, Gary R. Smith
VP Sales and Marketing, David E. Dykstra
Director Finance, Michael Shook

Stock: NASDAQ: HIPC
Financials: 2000 Sales (mil.): $108.5
1-Yr. Sales Growth: 12.2%
2000 Net Inc. (mil.): $0.2
1-Yr. Net Inc. Growth: (60.0%)
2000 Employees: 141
1-Year Employee Growth: (6.6%)

High Plains is the seventh largest of approximately 60 U.S. ethanol producers and owns three plants in Kansas, Nebraska, and New Mexico that collectively have the capacity to produce about 68 million gallons annually.

The company converts corn and milo into fuel-grade ethanol (blended with gasoline to reduce emissions) and industrial-grade ethanol for use in beverage alcohol, cosmetics, perfume, and vinegar. High Plains also sells its by-products, including carbon dioxide and distiller's grains used as cattle feed. To reduce its dependence on ethanol, the firm has launched a pilot program to produce glycerol for use in the cosmetics, pet food, and pharmaceuticals industries.

- **Indeck Energy**

600 N. Buffalo Grove Rd., Ste. 300
Buffalo Grove, IL 60089
Phone: 847-520-3212
Fax: 847-520-9883
Website: www.indeck-energy.com

Company Type: Private
Key Business: Energy from natural gas-fired, wood, coal-burning, and hydroelectric facilities that produce both steam and electricity
Key People: Chairman and CEO, Gerald R. Forsythe
President, Thomas M. Campone
CFO, Lawrence A. Lagowski

Financials: 2000 Sales (mil.): $190.0
1-Yr. Sales Growth: 5.6%

2000 Employees: 544 (est.)
1-Yr. Employee Growth: (1.1%) (est.)

Indeck Energy Services generates energy from 13 independent power projects and cogeneration plants in New England and the Midwest, and from one UK plant located near London. The company, founded in 1985, generates a capacity of 1,200 MW through natural gas-fired, wood, coal-burning, and hydroelectric facilities that produce both steam and electricity.

Affiliates Indeck Power Equipment and Indeck Operations supply power equipment for packaged steam systems and acquire and operate the company's power plants. Indeck has plans for a 1,100 MW plant in Michigan, which would nearly double the company's generating capacity.

- **International Automated Systems, Inc.**

Salem, UT — Phone: 801-400-0678 (Neldon's cell phone)
Website: www.iaus.com

Company Type:	Public
Key Business:	Geothermal turbines, digital wave modulation, automated payment systems, and fingerprint technology
Key People:	Neldon Johnson, President/Owner Legrand Johnson (son of Neldon)
Stock:	OTC: IAUS

Neldon is an inventor/engineer with his hands in many different technologies, including, but not limited to: automated payment systems, fingerprint technology, geothermal turbines, and digital wave modulation (DWM) for broadband usage. They have a successful beta test site of their automated payment systems at *U Check It* (a grocery store owned by Neldon) in Salem, UT.

Neldon gave us several brochures describing the different technologies, but for our purposes, we will focus on his geothermal turbine. Of interest is the fact that Neldon received a phone call from Dave Winder's office (Dept. of Community and Economic Development) while I was meeting with him—they had a meeting on May 14 at 2:00 to discuss his patented geothermal turbine technology. Since then, a contractual agreement is being written up between PacifiCorp and Neldon (Merrill Brimhall is the PacifiCorp contact). The contract allows Neldon to receive a penny for every kilowatt produced by the turbine. PacifiCorp wants Neldon to sign an exclusive agreement, which prevents competitors from using the technology in seven western states. Neldon has an agreement with New Mexico, and they are paying him 1 cents per kilowatt as well. Los Alimos Laboratories have agreed to work to improve the process/patent of the geothermal turbine.

The patented geothermal turbine, according to Neldon, is 1/100 of the cost of original turbines. It costs $100,000 to make his geothermal turbine and $1 million to drill a well. A huge cost savings occurs because his turbine doesn't use cooling towers and reduces the concerns over depleting aquifers. The geothermal turbine is a unique "marriage" between rocket ship technology and existing geothermal turbines. The turbine is designed to burn hydrogen and oxygen together (making steam) and have a nozzle on the end imitating rocket ship technology.

Neldon's geothermal turbine, at the very least, match efficiency rates of Pacificorp plants at low temperatures; and is more efficient at higher temperatures. At 1500 degrees, his turbine has an efficiency rate of 68%. GE is backed up three years in their orders for turbines. Traditional gas turbines cost 6-7 cents/KW and his geothermal turbine costs .5-1 cents/KW. In using the known geothermal sites in the U.S., we have could provide power to the whole world. Neldon wants a licensing agreement where he gets a percentage profit on power produced. He is also looking into the option of receiving a grant for any "clean energy" he can produce above and beyond what is currently being produced at the Milford plant. His company recently purchased some land in southern Utah containing hot springs and they are planning on starting a geothermal plant there.

- **Kyocera Solar, Inc.**

Kyocera (parent company)

7812 E. Acoma	Phone: 480-948-8003
Scottsdale, AZ 85260	Fax: 480-483-2986
Toll Free: 800-223-9580	

Website: www.kyocerasolar.com

Company Type:	Subsidiary of Kyocera
Key Business:	Ceramics, electronics; has subsidiaries in solar and other industries
Key People:	President, CEO, and COO; Douglas Allday
	CFO and Corporate Secretary, Jeffrey C. Brines
	VP Marketing and Sales, Ronald Kenedi
Stock:	NYSE: KYO, TOKYO Stock Exchange
Financials:	2000 Sales (mil.): $7,779
	1-Yr. Sales Growth: 29.5%
	2000 Net Inc. (mil.): $489
	1-Yr. Net Inc. Growth: 104.2%

Formerly a Coors family enterprise, Kyocera Solar makes solar electric power systems for areas where connecting to the power grid is impossible or too costly. The company is a subsidiary of Kyocera International, which is owned by Japan's Kyocera Corporation (ceramics and electronic components). Kyocera Corporation bought Kyocera Solar in 1999 to broaden its market beyond Asia.

Kyocera Solar's products are used in wireless communications equipment, traffic signals, and remote monitoring systems for gas pipelines or water tables. The company also makes solar-powered water pumping systems, solar electric systems for boats, recreational vehicles, refrigerators, and freezers.

Kyocera Solar sells directly to industrial users through more than 1,000 distributors and independent dealers and by mail order. Their solar systems are a combination of their own Durovolt photovoltaic modules and electronic controllers with components from manufacturers.

- **MidAmerican Energy**

666 Grand Ave.	Phone: 515-242-4300
Des Moines, IA 50309	Fax: 515-281-2389
Website:	www.midamerican.com

Company Type:	Private
Key Business:	Diversified energy producer—geothermal, hydroelectric, and natural gas power plants; real estate brokerage
Key People:	Chairman and CEO, David L. Sokol President and COO; CEO, Northern Electric and MidAmerican Energy: Gregory E. Abel
Financials:	1999 Sales (mil.): $4,398.8 1-Yr. Sales Growth: 72.2% 1999 Net Inc. (mil.): $167.3 1-Yr. Net Inc. Growth: 31.8% 1999 Employees: 9,700 1-Year Employee Growth: 161.9%

MidAmerican Energy Holdings, formerly CalEnergy Company, is a diversified energy producer and distributor who builds and operates geothermal, hydroelectric, and natural gas power plants worldwide. Deregulation of the electric utility industry led the former CalEnergy to diversify within the US (partly by purchasing MidAmerican Energy Holdings, from which it took its name) and to expand its business internationally. CalEnergy's long history as an alternative energy producer with environmentally friendly and renewable power resources places MidAmerican Energy Holdings in a strong position to compete in the open market with fossil-fuel-based utilities just beginning to go green.

The company, which once focused almost solely on geothermal energy, is still a major independent producer of geothermal power with operations in Australia, the Philippines, Poland, the UK, and the US. The company is now diversifying its power assets and owns energy companies in different sectors of the industry. Subsidiary Northern Electric and Gas, a UK electricity company, serves about 1.5 million electricity customers and about 600,000 gas customers. MidAmerican Energy Company generates electricity (primarily from coal) and distributes it to about 663,500 customers in the midwestern US; it distributes natural gas to about 638,000 in the same region. MidAmerican Energy Holdings' residential real-estate brokerage, HomeServices.Com, operates in 12 states in the US.

Rankings:

- #495 in Hoover's 500

- **Royal Dutch/Shell**

30, Carel van Bylandtlaan	Phone: 31-70-377-9111
2596 HR The Hague, The Netherlands	Fax: 31-70-377-3115
www.shell.nl	

Company Type:	Joint Venture of Royal Dutch Petroleum and Shell Transport
Key Business:	
Key People:	Chairman and Group Managing Director, Chairman and Managing Director of the "Shell" Transport and Trading Company, CEO; Sir Mark Moody-Stuart VC and Group Managing Director, President and Managing Director, Royal Dutch Petroleum; Mr. Maarten A. van den Bergh
Stock:	NYSE: RD, NYSE: SC
Financials:	2000 Sales (mil.): $149,146 1-Yr. Sales Growth: 41.6% 2000 Net Inc. (mil.): $12,719 1-Yr. Net Inc. Growth: 48.2% 2000 Employees: 90,000 1-Yr. Employee Growth: (6.2%)

Royal Dutch/Shell is the world's second-largest oil and gas conglomerate after losing the crown to Exxon Mobil. The oil giant has operations in more than 135 countries and proved reserves of 9.8 million barrels of oil and 58.5 trillion cubic feet of natural gas. Royal Dutch/Shell owns or has interests in about 50 refineries worldwide and sells fuel through more than 46,000 service stations. The company also has oil transportation, chemical manufacturing, and solar power development businesses.

Royal Dutch/Shell is investing heavily in renewable energy technologies. "The company's solar business rivals that of competitor BP Solar, with projects in Switzerland, South Africa, Holland, and other countries with remote generation needs,"(Reed Wasden Report, November 17, 2000). They are currently working on two wind projects.

Rankings:

- #10 in FT Global 500

- **SCNV Acquisition Corp.**

Omer Industrial Park, PO Box 3026
Omer 84965, Israel
Website:

Phone: 7-690-0950
Fax: 7-690-0953

Company Type:	Public
Key Business:	Photovoltaic panels and cells, monocrystals for electronic chips, metal alloys to reduce emissions, and electronic pocket dictionaries/translators
Key People:	Chairman, Emmanuel Althaus President and CEO, Herman Branover EVP, CFO, and Secretary; Shaul Lesin
Stock:	OTC: SAQCE
Financials:	2000 Sales (mil.): $0.2 1-Yr. Sales Growth: 155.2% 2000 Net Inc. (mil.): ($2.2) 2000 Employees: 9 1-Yr. Employee Growth: (64.0%)

SCNV Acquisition converts sunlight into electricity and turns crystals into chips. The firm focuses mainly on environmentally oriented technologies created by scientists who immigrated to Israel from Russia and other countries.

SCNV is developing advanced double-sided photovoltaic panels as well as a process for the production of large monocrystals for use in electronic chips and photovoltaic cells. The company is also working on a micro-gravity process to produce metal alloys and a carbon dioxide absorption process that removes hazardous emissions and markets electronic pocket dictionaries/translators.

- **Sharp**

22-22 Nagaike-cho
Abeno-ku, Osaka 545-8522, Japan

Phone: 81-6-6621-1221
Fax: 81-6-6627-1759

Web Site: http://sharp-world.com

Company Type:	Public
Key Business:	Digital copiers, PCs, fax machines, communication and information devices, LCDs, TVs, home appliances, integrated circuits, and solar cells
Key People:	President, Katsuhiko Machida

Stock:	OTC: SHCAY
Financials:	2000 Sales (mil.): $17,580 1-Yr. Sales Growth: 20.0% 2000 Net Inc. (mil.): $267 1-Yr. Net Inc. Growth: 585.7% 2000 Employees: 49,748 1-Year Employee Growth: (13.5%)

Sharp generates about a third of its sales from digital copiers, PCs, fax machines, and other communications and information devices. However, the company built its reputation as a leading maker of liquid crystal displays (LCDs), used in everything from airplane cockpits to PCs to pinball machines. Sharp also makes TVs and other home electronics equipment; refrigerators, microwaves (global #1), and other home appliances; and integrated circuits (ICs) and other electronic components.

It has now made LCDs the core of its corporate growth strategy. Sharp is also focusing on high-margin ICs such as those used in cellular phones, and it seeks to expand its market position in photovoltaic solar cells.

Sharp, which generates about 65% of its sales within Asia, has shifted some production away from Japan to lower costs.

Rankings:

- #206 in FT Global 500
- Nikkei 225

- **Spire Corporation**

1 Patriots Park
Bedford, MA 01730-2396
Toll Free: 800-510-4815
www.spirecorp.com

Phone: 781-275-6000
Fax: 781-275-7470

Company Type:	Public
Key Business:	Photovoltaic manufacturing equipment, biomedical ion beam technology, optoelectronics
Key People:	Chairman, President, and CEO; Roger G. Little VP, CFO, Treasurer, Principal Accounting Officer, and Clerk; Richard S. Gregorio VP, General Manager, Spire Solar; Stephen J. Hogan
Contact:	Maurice Covino, 781-275-6000, mcovino@spirecorp.com
Stock:	NASDAQ: SPIR

Financials: 2000 Sales (mil.): $12.9
1-Yr. Sales Growth: 8.4%
2000 Net Inc. (mil.): ($0.8)
2000 Employees: 94
1-Yr. Employee Growth: 6.8%

Spire Corporation provides solar electric systems for distributed power generation and is a leading supplier of solar electric module manufacturing equipment, turnkey production lines, and solar energy businesses. Spire equipment has been installed in 144 factories in 42 countries and more than 90 percent of the photovoltaic modules in use today were manufactured with Spire equipment.

The company's biomedical division uses ion beam technology to modify the surfaces of artificial valves and other medical devices to reduce friction and infective agents. About three-fourths of Spire's sales come from contract R&D, services, and technology licensing. The 1999 sale of Spire's optoelectronics unit to Methode Electronics raised $13 million for the company to invest in its other two segments.

Spire recently sold two “SPI-SUN SIMULATORS” to BP Solar. These simulators will be used in BP Solar Fairfield's production line of modules using patented Apollo integrated thin film technology. BP Solar, a unit of London-based BP, is one of the world's largest solar electric module producers with manufacturing operations in the U.S., Spain, India, Australia, and Malaysia.

“We are pleased that BP Solar, with more than 15 Spire simulators in use worldwide, continues to recognize our expertise in testing and manufacturing equipment reliability.” Roger G. Little, President and CEO of Spire Corporation

The “SPI-SUN SIMULATOR”, which is the international standard used by PV module manufacturers and testing laboratories, measures the electrical performance of modules before they are installed, (Business/Technology Editors, *Business Wire*; Bedford, MA; May 9, 2001).

- **Trigen Energy Corporation**

One Water St.
White Plains, NY 10601-1009
Website: www.trigen.com

Phone: 914-286-6600
Fax: 914-286-6677

Company Type: Subsidiary of Suez
Key Business: Co-generating energy systems—hot water, biomass, electricity, natural gas, coal, oil, municipal waste, and wood
Key People: Chairman, Managing Chairman and CEO, Societe Generale de

Belgique; Christine Morin-Postel
President and CEO, Richard E. Kessel
VP and CFO, Martin S. Stone

Stock: Euronext Paris: SZE
Financials: 1999 Sales (mil.): $280.4
1-Yr. Sales Growth: 15.7%
1999 Net Inc. (mil.): $11.2
1-Yr. Net Inc. Growth: 77.8%
1999 Employees: 846
1-Yr. Employee Growth: 13.6%

"This highly efficient and environmentally superior project displaces old fossil fuel generation and makes renewable energy readily available to local consumers at economically attractive prices." *Rich Kessel, president and CEO of Trigen Energy*

Trigen Energy Corporation is a leading developer, owner and operator of industrial, commercial, institutional and district energy systems in North America. Trigen uses highly efficient energy technologies including combined heat and power (CHP) systems to deliver innovative and reliable utility solutions. By reducing the amount of fuel consumed and the air pollution emitted into the environment, Trigen demonstrates that economic and environmental sustainability are compatible. Trigen is wholly owned by Elyo, a subsidiary of Tractebel, the energy arm of Suez.

"This is clearly a situation in which everybody wins. By using chipped tree trimmings to generate electricity, we greatly reduce our burning of coal and oil. This will significantly cut air emissions and reduce greenhouse gases that contribute to global warming." *Anders Rydaker, DESP President*

Trigen Energy co-generates energy, producing steam or hot water (86 percent), electricity (seven percent), and chilled water (seven percent) at several of its 51 cogeneration and district energy facilities. Its 6,100 MW generating capacity serves more than 1,500 industrial and commercial customers at 36 locations in Canada, Mexico, and the US. The company's gas turbines, diesel engines, boilers, and chillers are fueled by natural gas, coal, oil, wood waste, municipal solid waste, and scrap. The company also markets energy products and services, packages steam turbines, provides energy management, and converts biomass to energy. Trigen Energy is a subsidiary of the ELYO unit of French conglomerate Suez.

President Bush, prior to the national energy plan recommendations of Cheney's 2001 task force, visited the site of a future wood waste biomass energy project owned and operated by St. Paul Cogeneration. Trigen-Cinergy Solutions and Market Street Energy, an affiliate of District Energy St. Paul (DESP), formed St. Paul Cogeneration. DESP provides heating and cooling services to business, governmental, institutional and residential buildings in St. Paul. Cinergy Solutions, an affiliate of Cinergy Corp., Cincinnati, Ohio, will build the 25 megawatts biomass plant.

The biomass project, scheduled for completion in late 2002, will burn 280,000 tons a year of wood waste that is identified as a pollution problem. The project will be the largest wood-fired combined heat and power plant serving a district energy system in the United States.

Northern States Power, a subsidiary of Xcel Energy, will purchase at least 153,300 MWh from plant, enough energy to supply approximately 20,000 homes. There will be a total combined electric and thermal capacity of 98 megawatts.

In addition, thermal energy will supply approximately 80 percent of the annual needs for the DESP system, which is currently fueled predominately by coal. The wood-burning facility will reduce the current plant's sulfur dioxide emissions by 80 percent. More than 283,000 tons per year of carbon dioxide, the chief greenhouse gas, will be reduced in the conversion from coal to wood.

> ***"This project demonstrates you can have it all - more energy and a cleaner environment. The President, in touring the energy facility, helps showcase the fact that a long-term energy solution consists not just in increasing supply, but also in promoting efficient technologies and environmental improvements."***
> *James E. Rogers, Chairman, CEO of Cinergy Corporation*

This process can operate at more than double the efficiency of conventional electricity-only power plants. An additional benefit is that more than 280,000 tons of wood waste that would have been disposed of on land or subject to unregulated burning will be used to power the facility.

Combined heat and power facilities are among the most energy-efficient solutions to the need for more electric generation. The process captures more than 50 percent of the waste heat generated by traditional generation systems and converts it to steam to be used as a means of producing energy, (Hoovers' News Online, "President to Visit Site of Future Biomass Power Plant; St. Paul, MN; May 15, 2001).

Rankings:

- CAC 40
- Euronext 100
- #184 in FT Global 500

- **Vestas**

Vestas Wind Systems A/S
Smed Sørensens Vej 5
DK-6950 Ringkøbing
Denmark
Website: www.vestas.com

Phone: 45-96-75-25-75
Fax: 45-96-75-24-36

Company Type: Public
Key Business: Wind turbines
Key People: Chairman, Bent Erik Carlsen
Contact: vestas@vestas.dk

Stock: KFX: VWS, ID code/ISIN: DK0010268606
Financials: Shares have risen almost 80% in the past year
2000 sales (DKK'000): 6.450.598
2000 net profit (DKK'000): 568.699

Vestas, a Danish company, is the world's largest manufacturer of wind turbines with 30% of the worldwide market share and sales of a total capacity of 1.147 megawatts. With the use of wind power growing at an annual rate of 40% worldwide, Vestas is one of Europe's hottest companies and its shares have risen almost 80% in the past year. Vestas has erected wind turbines in more than 35 markets spread over most of the globe.

Vestas primarily produces big turbines with an effect of 600 kW. The turbines have three rotors and a designed life of 20 years. Scandinavia generates 12 percent of turnover, while the rest of Western Europe generates 74 percent.

- **WorldWater Corp.**

55 Rte. 31 South
Pennington, NJ 08534
www.worldwater.com

Phone: 609-818-0700
Fax: 609-818-0720

Company Type: Public
Key Business: Solar systems for pumping water and generating electricity
Key People: Chairman and CEO, Quentin T. Kelly
President and COO, James S. Farrin
Stock: NASDAQ: WWAT.OB
Financials: Inquire at: Investor@Worldwater.com

WorldWater provides turnkey solar systems used for pumping well and irrigation water and for generating household electricity in remote areas, especially in developing countries.

Using proprietary low-maintenance "AquaSafe" and "AquaMax2200" pumps, and its "SolPower" generating system; WorldWater has set up solar pumping and solar electrical systems in Asia, Africa, and South America. Major customers include government agencies in Pakistan, the Philippines, and Sri Lanka.

- **York Research**

280 Park Ave., Ste. 2700 W.
New York, NY 10017
Website: www.yorkresearch.com

Phone: 212-557-6200
Fax: 212-557-5678

Company Type:	Public
Key Business:	Cogeneration and renewable energy power plants—wind, gas-fired
Key People:	Chairman, President, and CEO; Robert M. Beningson EVP, CFO, Chief Accounting Officer, and Secretary; Michael Trachtenberg
Stock:	NASDAQ: YORK
Financials:	2000 Sales (mil.): $22.5 1-Yr. Sales Growth: (97.7%) 2000 Net Inc. (mil.): ($31.1) 2000 Employees: 35 1-Year Employee Growth: (38.6%)

York Research, founded in 1959, develops independent cogeneration and renewable energy projects. York Research operates and has stakes in two New York cogeneration power plants (generating both electricity and steam) that produce 324 megawatts for utility Consolidated Edison Company of New York. The firm has wind-power projects in Texas (34 megawatts) and a natural gas-fired plant in Trinidad and Tobago (225 megawatts).

Overview of Renewable Energy Industry

There is an ongoing transformation of corporate thinking about the environment and a growing sense that being clean and green is a promising business opportunity and a core management skill, not just a matter of checking off the appropriate regulatory boxes. “Environmentally friendly behavior equals money,” says Georg Schett, a senior vice president at ABB. Even hardheaded market types are getting the message. Last October, Merrill Lynch's London office launched a fund that invests in new energy technologies; it was immediately oversubscribed, despite the global meltdown in tech shares. “The fundamentals in this sector are so strong that it moves even in a declining market,” says Robin Batchelor, the fund’s manager.

Eager to get on the bandwagon, oil companies like BP and Shell are gamely trying to reposition themselves as energy companies, though the overwhelming bulk of their activity will be in oil, gas, and chemicals for decades to come. BP has gone so far as to run ads that playfully link its initials, which used to stand for British Petroleum, to the words “beyond petroleum.” More significantly, Shell assigns an internal carbon cost to all new projects that involve oil and gas, as if it were liable to pay a tax on such pollution in the real world. At the lower end of the corporate ladder, entrepreneurs are tinkering with everything from turbines to cooking pots.

Europeans especially seem to have a sense of urgency about developing new sources of energy. Perhaps as a hangover from wartime shortages and rationing, perhaps because land and resources have always been hotly contested, Europeans are comparatively frugal. On average, they consume about half as much energy per capita as Americans. And they are willing to pay a higher price for it. Europeans routinely spend $50 to fill the tank of a small car, which is why there are not many SUVs on European roads. Although protests last year over rising gas prices hinted that the upper limits of this form of taxation had been reached, there is still no pressure to bring prices down to American levels either, (Excerpts taken from Henry Muller's Winds of Change in Monday, March 19, 2001, *Fortune*).

Additional Biomass Industry Information

Wasatch Energy Systems performs local biomass production. John Crofts, at 801-771-3032 ext 36, is the lead contact; given to us by Craig Bingham, Dept.of Community and Economic Development MBA Intern.

Additional Geothermal Industry Information

GE is backed up three years in their orders for turbines. In using the known geothermal sites in the U.S., we have could provide power to the whole world.

Forty-eight percent of geothermal heat pumps were shipped to installers and 38 percent went to wholesale distributors in 1998. Eight percent were shipped to retail distributors, while 3 percent went to end-users.

Geothermal Heat Pump Shipments by Customer Type and Model Type, 1998
(Number of Units)

Customer Type	ARI-320	ARI-325/330	Other Non-ARI Rated GHPs	Total
Exporter	0	109	0	109
Wholesale Distributor	5,093	8,474	810	14,377
Retail Distributor	0	3,043	179	3,222
Installer	4,517	13,329	583	18,429
End-User	0	959	35	994

Others	900	128	107	1,135
Total	**10,510**	**26,042**	**1,714**	**38,266**
Energy Information Administration, "Annual Geothermal Heat Pump Manufacturers Survey."				

Geothermal heat pump shipments, based on the Energy Information Administration, Annual Geothermal Heat Pump Manufacturers Survey, shows that manufacturers shipped 38,266 geothermal heat pumps in 1998, an increase of two percent from the 1997 total of 37,434.

The proportion of geothermal heat pumps shipped to each census region in 1998 was as follows: the South (42 percent), the North Central (32 percent), the Northeast (14 percent), the West (10 percent) and exports (1 percent).

Additional Hydroelectric Industry Information

Dams west of the Mississippi are owned by the government. However, the government contracts power companies to manage the dams. So, the money is made by the regulated utility companies. There is no defined *leader* in the industry as the companies don't own the dams.

Additional Wind Industry Information

The use of wind power growing at an annual rate of 40 percent worldwide.

The new wind frontier is the shallow seas surrounding Denmark, where winds are stronger and steadier than onshore, adding 50 percent to their energy content. From 2002 to 2008, wind turbines that can produce 750 megawatts of electricity--enough to meet the needs of 625,000 Danish households--are scheduled to be installed offshore, and 150 megawatts of capacity will be added each year after.

Flemming Rasmussen, a senior research scientist at the government-sponsored Riso Lab, notes that blades seem to grow by 15 feet per year as companies find solutions to manufacturing obstacles. The newest offshore turbines have rotors with a diameter of up to 230 feet, longer than the wingspan of a Boeing 747. Although five nations (Denmark, Germany, the U.S., Spain, and India) now account for 80 percent of the world's wind turbines, they exist in 50 countries. Revenues reached $4.5 billion in 2000.

Denmark's biggest wind farm, just off Copenhagen's harbor, will soon meet about three percent of the city's energy demand. Wind power is big business in Denmark. The country generates 13 percent of its electricity from wind turbines and is well on its way to meeting its target of 50 percent by 2030.

The wind industry leaders are the four Danish companies that enjoy more than 50 percent of the world market for turbines: Vestas, NEG Micon, Nordex, and Bonus Energy. But as wind has become economically viable, the competition has increased. Shell has put together two wind projects, and ABB is planning a Swedish test for a turbine called Windformer that it says will revolutionize the industry because of its simpler components and the ability to transmit electricity over longer distances.

Swedish-Swiss ABB has shed traditional activities such as the construction of big power plants and locomotives so that it can move aggressively into new energy businesses, including the development of windmills, microturbines, and fuel cells.

Two U.S. utilities, PacifiCorp and FPL Energy, have announced their intention to build the world's largest wind farm on the Oregon- Washington border, (Excerpts taken from Henry Muller's Winds of Change in Monday, March 19, 2001, *Fortune*).

Additional Solar Industry Information

Caixa Economica Federal (CEF), the Brazilian state-owned savings bank, will today open a R$ 100m credit line to finance the purchase of residential solar heaters by some 125,000 households. The price of each unit is estimated at R$ 800. With the move, CEF hopes to help the government to reduce electricity consumption in the country by 20 percent.

Although the global solar industry is growing at more than 20 percent a year (2000 revenues: about $1.5 billion), it will be at least a decade until it becomes economically competitive with conventional sources. The cost of solar energy in Europe varies, but it's generally between 20 and 25 cents per kilowatt-hour, much more than conventional energy. But costs have fallen 50 percent in the past decade, and BP expects the learning curve to continue to drive prices down. Solar power, moreover, retains an almost mystical attraction for those seeking the Holy Grail of clean energy. It does not require the capital investment of, say, a biomass plant and does not make noise or use lots of land, as windmills do. "Solar's great strength," says BP group vice president Andrew Mackenzie, "is its acceptability," (Henry Muller, Winds of Change, March 19, 2001, *Fortune*)

Most types of solar/renewable energy products can be purchased online. For example, go to http://www.jademountain.com

Shipments of Domestic Solar Collectors Ranked by Top Five Origins & Destinations, 1997 and 1998				
Origin/Destination	**1997 Shipments**		**1998 Shipments**	
Thousand	Percent of	Thousand	Percent of	

	Square Feet	U.S. Total	Square Feet	U.S. Total
Origin				
California	2,308	38	2,651	48
New Jersey, Florida, and Hawaii	2,656	44	2,596	47
Texas	*	*	160	3
Puerto Rico	*	*	63	1
New York	957	16	34	1
Top Five Total	**5,921**	**98**	**5,504**	**100**
Destination				
Florida	3,975	49	3,306	45
California	1,781	22	1,629	22
Arizona	500	7	412	6
Nevada	*	*	267	4
Hawaii	204	3	267	4
Oregon	145	2	*	*
Top Five Total	**6,605**	**83**	**5,880**	**81**

* = Not included in top 5 States for either 1997 or 1998.
Energy Information Administration, "Annual Solar Thermal Collector Manufacturers Survey."

Exports went mainly to Canada (32.3 percent), Austria (14.8 percent), Mexico (13.5 percent), and Germany (11.8 percent).

Low-temperature solar collectors represented 94 percent of total shipments while medium-temperature collectors were responsible for almost six percent. High-temperature collectors are used by utilities and nonutilities in experimental grid electricity programs and represent less than one percent of total shipments. U. S. manufacturers from six states (California, New Jersey, Florida, Hawaii, Texas, and New York) and Puerto Rico manufactured nearly 100 percent of U.S. solar thermal collectors in 1998.

Annual Shipments of Solar Thermal Collectors by Type, 1987-1998 (Thousand Square Feet)

Year	**Low-Temperature**		**Medium-Temperature**		**High-Temperature Total Shipments**
	Total Shipments	Average per Manufacturer	Total Shipments	Average per Manufacturer	
1987	3,157	263	957	19	3,155
1988	3,326	416	732	16	4,116
1989	4,283	428	1,989	55	5,209
1990	3,645	304	2,527	62	5,237
1991	5,585	349	989	24	1
1992	6,187	387	897	26	2
1993	6,025	464	931	28	12
1994	6,823	426	803	26	2

1995	6,813	487	840	32	13
1996	6,821	487	785	41	10
1997	7,524	579	606	29	7
1998	7,292	607	443	23	21
Energy Information Administration, "Annual Solar Thermal Collector Manufacturers Survey."					

The value of total shipments was $28.4 million in 1998, a decrease of 2 percent from 1997. The average price for total shipments increased three percent, from $3.56 per square foot in 1997 to $3.66 per square foot in 1998.

The residential sector was the largest market for solar collectors, totaling nearly 7.2 million square feet, or 92 percent of total shipments. The commercial sector was the second largest, with 0.5 million square feet (6.7 percent). The largest end use for solar collectors shipped in 1998 was for heating swimming pools, consuming 7.2 million square feet (93 percent) of total shipments. The second-largest use was for domestic hot water heating (6 percent). The value of shipments of complete systems increased from $14.3 million in 1997 to $15.2 million in 1998.

Companies Involved in Solar Thermal Activities by Type, 1997 and 1998

Type of Activity	1997	1998
Collector or System Design	22	22
Prototype Collector Development	12	12
Prototype System Development	7	10
Wholesale Distribution	20	20
Retail Distribution	14	16
Installation	11	12
Noncollector System Component Manufacture	9	9
Energy Information Administration,"Annual Solar Thermal Collector Manufacturers Survey"		

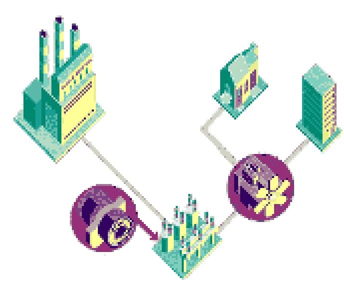
Distributed Generation

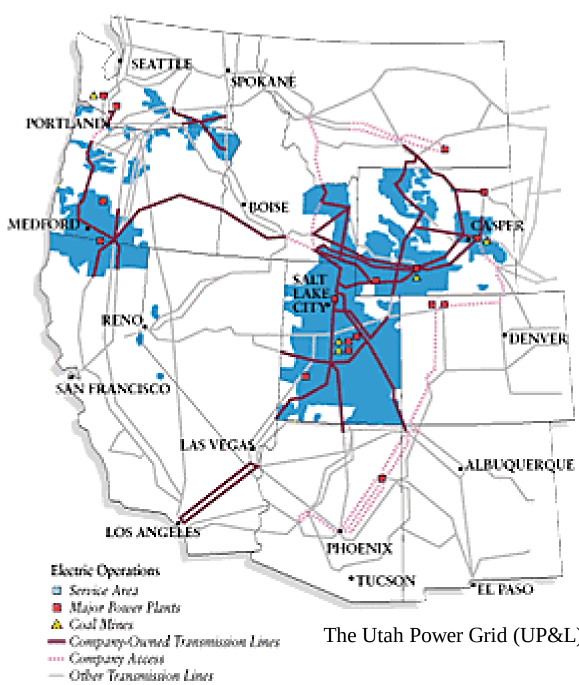
Power that Hits Close to Home

"Though distributed generation (small generation located within the distribution system) could be part of the solution, it has encountered its own set of problems. The independent system operators do not like dealing with smaller generators. It is much easier to work with a few large plants than with a bunch of smaller guys (10 MW and under). So at the same time that the state is suffering from massive power shortages, the ISO is ignoring federal rules governing purchase and sale from cogenerators, and imposing rigid constraints on the ability of smaller generators to sell power into the transmission grid."

William marcus, JBS, Inc.

Alternate energy technologies such as fuel cells and microturbines have potential and real applications in distributed generation. Electricity generation originating off-grid such as on-site diesel generators and natural gas-fired turbines have existed for years, and are not considered high-tech by any means. However, power generation using cutting-edge technologies brings distributed generation to the forefront as a solution to the increasing grid-based power problems.





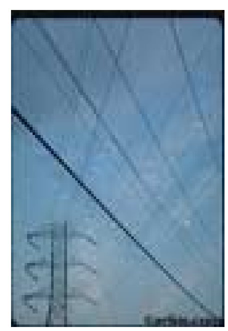
The Utah Power Grid (UP&L)

Distributed generation is "the integrated or stand-alone use of small, modular electric generation close to the point of consumption," (Arthur D. Little 2000, 2). "Integrated" distributed generation refers to the generators link to the grid. Integrated systems are able to transfer power to the grid. Stand-alone systems are not able to transfer power to the grid. The chart to the right shows how distributed generation would work in relationship to the grid. On the utility side of the meter, distributed generation could generate peaking capacity, to help the base load generator (the power plant) produce enough power for peak hours. On the consumer side of the meter, a distributed generating system would allow a building or home to be powered by its own on-site power source, but in many cases, would still have the benefit of being attached to the grid. Either the grid or the generator would act as a backup power source: distributed generation is justified largely on the grounds that power is always available, because there is always a backup.

The grid (left; from Pacificorp, Inc.), while it offers centralized production and diffuses the costs of generation across many users, provides "low-quality" power—power service that is interruptible. Because power production, transmission, and distribution infrastructures often fail, the power they provide is of lower quality than solutions that guarantee power availability at all times.

Additionally, concerns over emissions from power plants, electricity industry restructuring (deregulation), and reducing transmission congestion and growth make the prospect of private electricity generation attractive to users and lawmakers alike (Boedecker, et al. 2000, 1). Alternative distributed generation systems (fuel cells, microturbines, solar cells, etc.) generally have lower emissions of greenhouse gasses and particulate matter than traditional utility generation emits.

On-site power generation also fits into the trend toward utility deregulation, because in about half the states, industrial users may purchase power from a utility of their choice, making the choice to generate their own power a viable option.



The growth of transmission systems, which are generally regarded as too big and too inefficient (see the section of this report entitled "Superconductors"), may be lessened if firms are given the option of disconnecting from the grid and becoming their own power suppliers. But barring disconnection, the transmission system may only have its load alleviated during peak hours, as firms choose during those hours to generate their own power. At peak hours, there is a greater probability of transmission failure due to bottlenecking and insufficient power supply.

However, industry imperatives for power reliability have been the most compelling causes of increased investment in distributed generation. For example, some California power plants recently chose to go off-line for maintenance, interrupting the power supply, and creating electricity shortages. Also in California, utilities and wholesalers are unable to purchase sufficient power because the regulatory scheme has affected their ability to recover their costs, and so has affected the utilities' credit ratings. Hence, insufficient transmission and distribution mechanisms have shortened supply even further, virtually guaranteeing that power service to end users will be interrupted in certain areas.

Other interruptions are created by natural means—storms, earthquakes, and other disasters can physically damage generation facilities and transmission or distribution lines, causing power outages.

Such outages are simply inconvenient for most residential users, while for others such as the elderly, power outages are often blamed for heat-related deaths. In the health care industry, power outages could have devastating effects for patients.

Industrial power users, especially in the energy-intensive high-tech industries, find interruptions in electrical service unacceptable. Power outages of even one hour cost millions of dollars in interrupted production. For example, "two days of rolling blackouts in California [during March of this year] cost about $1.7 billion in lost productivity," (Patton 2001). In response to a series of power outages, a bank in Omaha installed a gas-fired fuel cell generator on site. The generator cost the bank about the same as a one-hour power outage would have cost them.

"Two days of rolling blackouts in California cost about *$1.7 billion* in lost revenues,"

Since this uninterruptible "quality" is lacking from power on the grid, many industrial and health care firms have taken to distributed generation systems to ensure that power for their computers, machines, and industrial processes is always available.

On-site power generation systems range in size from small 50 kW, refrigerator-sized microturbines (Capstone's microturbine, shown right) to large 250 kW fuel cell power generators (Ballard's industrial fuel cell generator, shown left).

The costs of installing distributed sources of power generation are

comparatively high, and market penetration by distributed generation manufacturers is expected to increase as the number of years required to recoup capital and installation costs decreases (Boedecker, et al. 2000, 2). But industry leaders contend that the market for distributed generation is based on reliability, and not on cost comparisons with grid power.

As shown above, a cost comparison between the cost of installation and the cost of a one-hour power outage is more appropriate than comparing installation of distributed generation capacity with purchasing new grid line capacity. However, as the prices of power increase across the country, distributed generation begins to look more attractive, even on that scale. While evidence is anecdotal, it is mounting. Silicon Valley technology companies are responding not only to the unreliability of power in their state, but also to the volatility of the market (Patton 2001). Similarly, the New York City Police Department found that purchasing a fuel cell generator to power their electronic criminal surveillance system was $200,000.00 cheaper than purchasing a grid line upgrade.

However, disconnecting from the grid or generating power on-site while still remaining connected with the grid carries with it additional costs—exit fees charged by utilities to recover sunk capital costs from the departing firm; and backup fees, which reflect the costs associated with maintaining grid capacity even when it is not being used, for the purpose of having power available if the firm needs it. In California, exit fees are as high as $6.40 per kilowatt hour generated on site (2001).

Barriers to Distributed Generation

- **Immature Technology**
- **Cost competitiveness with the grid**
- **Siting and Permitting**
- **Technical problems with grid/generator integration**
- **Regulatory issues**

"Distributed generation will not make utilities irrelevant."

These additional costs dilute the attractiveness of distributed generation, making it an unrealistic investment for most firms (2001). A power industry executive reports that, "A niche market may form around the quality issue, but firms will remain connected to the grid and pay a back-up fee," or other fees related to utility capital costs. Among other industry leaders, there seems to be broad agreement: "Distributed generation will not make utilities irrelevant. [Distributed generation] is a niche application, not a replacement for base-load capacity;" and "Distributed generation is about 10 years away from competing with big power in terms of cost, but the current market is reliability and quality, not cost effectiveness."

However, distributed generation investments are currently limited because of several market and regulatory factors (list that follows taken from California Energy Commission, *The Role of Energy Efficiency and Distributed Generation in Grid Planning: Report to the Governor and Legislature,* 2000). First, the technology is immature. Fuel cells, though they promise greater efficiencies and less emissions than power-plant production, are not developed nor reliable enough to promise true high-quality power. Microturbines, which are usually gas-fired, are much more developed, but still require back-up generators in case of turbine failure.

Second, the cost of distributed generation is not competitive with grid power. Although, as has been shown, there is industry-wide consensus that cost is not the primary force in the market for distributed generation, costs can be minimized through increased efficiencies (increased gas efficiency, cogeneration of heat and electricity, etc.).

Third, siting and permitting of generators is difficult in some states, especially for larger generators and mini-power plants. Diesel generators are restricted because of their high emissions, and so cannot be used for long periods of time.

"The current market is defined by reliability, not cost-effectiveness."

Fourth, interconnection of distributed generation with the grid is technically problematic, though software is currently available which facilitates the interconnection of the grid and on-site generators. Because they are technically difficult, installation and interconnection are time consuming and expensive.

Finally, regulatory issues with interconnection that act as barriers to investment in distributed generation. The DOE's Distributed Power Program reports that regulatory barriers to increased reliance on distributed power significantly hamper the development of this important market. The barriers enumerated by the DOE include technical and cost barriers to interconnection with the grid; utility pricing strategies; siting, permitting, zoning, and environmental restrictions; and current business models.

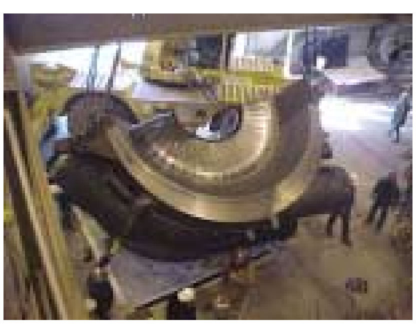
Regulatory Issues

- **Interconnection difficulty**
- **Utility pricing strategies**
- **Permitting and discriminatory environmental restrictions**
- **Full value of DG not considered in cost assessments**

The first regulatory issue, interconnection difficulty, exists not only for the technical issues addressed previously, but also because most states require an interconnection engineering study, which not only delays the installation process, but also adds significantly to its cost. Also, since there is no single standard and process for interconnection, agreements with power companies and utilities and governments are often reached through long negotiations. If there were a standardized process, application times for grid interconnection could be significantly shortened.

Second, utility pricing strategies fail to take into account the benefits of distributed generation to the overall grid system. Cost recovery charges discourage investment in distributed generation, and therefore, the other users of grid power miss out on the benefits and improved power quality from a reduced grid load. If power providers considered the benefits in peaking capacity and decreased load stemming from distributed generation, they might be more favorable to it. After all, by unburdening the grid, improving service and reliability, the value of grid power increases, and the price the utilities can charge for it will also rise, making exit fees unnecessary to cost recovery.

Third, users must receive permits for their on-site systems. Permitting is not standardized, and although it is designed to make sure distributed power systems are efficient and environmentally friendly, and to ensure that the interconnection is safe and reliable, critics say the permitting process really serves to slow down the process and chase other would-be distributed generation users out of the market. The DOE verifies that the permitting process can be very long and expensive and is currently working with several states to improve the permitting process. And critics of the process say that the emissions standards for distributed generation are more stringent than the standards for coal-fired power plants, which put out much more



emissions per kilowatt generated than several microturbines or fuel cells.

The last regulatory barrier is the prevailing utility business model, which relates to the cost issue above. The full value of distributed generation is not built into the utilities' current business models. Existing business practice reveals "the old regulated electricity industry dominated by vertically integrated utilities and central station power plants. New business models are needed to capture the values of non-utility owned distributed power in delaying or avoiding transmission and distribution system upgrades, the use of distributed power for ancillary services and for improving system reliability, power quality and reducing line losses. New competitive business models need to be developed that will allow the realization of full economic value of distributed power in competitive markets," (DOE 2001). This suggests that deregulation should be a priority to encourage the development of the distributed generation market.

Besides market and regulatory barriers, interconnection is unpopular with large utilities because they stand to be hurt if too many firms make distributed generation investments on the consumer side of the meter. That said, many utilities actually make investments in distributed generation research. The Electric Power Research Institute (EPRI) is an industry-funded organization focused on alternate energy research. Other utilities choose to invest in their own research of alternative energies. In both cases, the research conducted is not expected to be immediately useful, but is undertaken to establish industry competency in alternate forms of energy production, and in order to not lose out on promising developments being made by smaller firms in the alternative and distributed energy generation industries.

"Deregulation is a priority to encourage the development of the DG market."

Further, the development of retail electricity markets (deregulation) in many states has spurred the development of new products, and some traditional utilities have sought to profit from those markets. Utilities may find it profitable to offer distributed generation products on the utility side of the meter, and to bill users of the distributed capacity for the installation and operation costs.

Electricity industry investment in distributed generation is also interesting from a conservation and efficiency standpoint. According to the DOE, about 35 percent of the electricity consumed in Utah is never actually "consumed," but is lost off the transmission and distribution lines. By placing smaller generators closer to the end users, there is less line loss and increased generation and transmission efficiency, both of which decrease the costs and generation requirements of utilities.

"Thirty-five percent of the electricity generated in Utah is lost during transmission and distribution."

Whatever their motives, electricity firms that invest in research on distributed generation are not doing so to reduce the demands on them for power generating capacity. Distributed generation is not yet widely implemented nor developed enough to significantly reduce load requirements. Instead, some generating firms are simply taking advantage of the developing market for reliable power.

Distributed generation, unless it is harnessed across all private users simultaneously, has negligible impacts on actual peaking capacity and transmission infrastructure growth. However, increasing peaking capacity is only a long-term goal of distributed generation. In the short term, distributed generation's greatest value is to users, and not to utilities or distributors. Deregulation of the electric industry has provided a market-based incentive structure for the construction of new power generation capacity. Distributed generation can provide needed reliable power while new plants are being constructed and can soften the transition from regulation to restructuring for firms in states undergoing industry restructuring, because it reduces a firm's reliance on centralized power sources.

In the short term, distributed generation can also help power-intensive firms avoid high power prices at peak periods, since they can turn on their own generators at those times.

The long-term view of distributed generation is attractive, since distributed generation creates the possibility of spreading power generation across many users, reducing the effects of a central power outage, and eventually providing grid power from multiple locations, rather than from centralized power plants. As the value of high-quality power increases, and as technological advances improve the efficiency and reliability of alternative generation mechanisms, distributed generation may become a substitute for traditional power generation, rather than the compliment it currently represents. In the future, distributed generation may owned and operated by utilities, who may find it to be more cost effective than installing new plants or new grid wire.

The cost effectiveness of distributed generation depends on its integration with the grid. The benefits to the grid of independently generated power, combined with the reduced need for investment in distribution and transmission "wire" capacity combine to reduce the real cost of distributed generation, which at a capital and installation cost of several hundred to over one thousand dollars per kilowatt is substantially more expensive than constructing traditional centralized power sources.

Further, because most emerging distributed generation technologies are fueled by natural gas, and the deregulation of the natural gas industry has lowered gas prices, operation costs are competitive with the operation costs of traditional power plants. Further, the benefits of having access to power even when there is a shortage of grid power supply offset the costs of distributed generation.

Therefore, the real consumer cost of distributed generation would be of the following form:

$$Y = \alpha - [\beta + (\theta - \delta - \eta)],$$

where

Y represents the real costs of distributed generation;
α is the total of capital/installation plus the operating costs ($\beta + \theta$);
β is capital/installation costs;
θ , the operating costs of distributed generation;
δ , the reduced need for grid power;
η is the difference between investment in grid infrastructure ("wire") barring distributed generation and the projected investment in grid infrastructure with distributed generation.

Given this form, it is conceivable that by manipulating the numbers of distributed generation sites, the economies of scale of which large utilities once took advantage could disappear, since a greater distribution of power generation could conceivably lead to a very large η. But certainly, over-investment in distributed generation would lead to a very large value of β, while each new generator installation would not necessarily reduce the need for new wire installation by an equal proportion. We can envision, therefore, a diminishing return in η to each generator installed, the total of which is expressed by β.

Likewise, we can imagine an increasing return to the reduction in need for grid power with each installation of a new generator. However, at a certain point, we could expect the returns to peak and begin to decline, as more and more power is generated.

Further, we may need to include an additional variable in the cost function. The stranded costs strapped on the utilities as more end users opt for distributed generation increase the total costs to society of distributed generation. In this sense, α is ($\beta + \theta + S$), where S is the value of the stranded costs incurred by the utilities as more and more installations of distributed generation occur. S should increase as β increases, so it becomes less clear that the real cost of distributed generation is significantly lower than total cost, because the increase in stranded costs cancels the increase in stranded costs.

The new equation would be

$$Y = \alpha - [\beta + (\theta - \delta - \eta)] + S$$

In fact, depending on the number of firms investing in distributed generation capacity, the costs of maintaining power plants in order to simply provide backup power, or of letting traditional generation capacity sit idle may increase more rapidly than the costs of installing distributed generation. Therefore, at some point, real costs may exceed the total of capital and operating costs.

In an interview with the authors, an electric utility executive cautioned against making cost predictions, since the cost of installation is often compounded by the costs to the utilities of having stranded capacity sitting around. Arthur D. Little, Inc., cautions against modeling the costs of distributed generation. Costs are variable across different regions and communities, depending on regulatory structures and the actual availability of price signals. Where electric utilities are regulated, end users do not see price signals, and the costs of doing business will be different, as will the benefits of installing (or purchasing from a utility) local generation capacity (2000). Therefore, deriving some universal cost function is impossible and unwise. Suffice it to say that any cost/benefit analysis of distributed generation must include all the costs, including stranded costs, in the equation.

Cost savings are not the strongest justification for new distributed generation technologies. According to an analysis from Arthur D. Little, microturbine and fuel cell technologies offer different benefits to the distributed generation market. Fuel cell technology, because the cells can be stacked and bundled in indefinitely large units, could actually add to base-load generation capacity, while microturbines and other gas generators are most promising as reducers of peaking capacity, as well as being back-up generators for grid failures.

The benefits of distributed generation also include modularity, a design feature by which generation capacity can be added or taken away just by adding or subtracting units from the generator. Fuel cells can be stacked to increase capacity, and microturbines can be "ganged" in rows to add capacity. Conversely, adding capacity to a power plant can take years and millions of dollars of labor and inputs, and by the time it is constructed, may already be technologically obsolete.

Another benefit of distributed generation is that capacity is spread out. It is highly unlikely that power will fail at every distributed generation site simultaneously, and if a generator does fail, it only affects one building or one small area. A single power plant failure could halt production in an entire region.

Also, with a distributed generation strategy, the need for building new power plants and installing distribution wire and grid capacity is alleviated. Especially in deregulated markets, where the incentive to over-invest in the grid is reduced, staving off further investment in the grid could increase profits for utilities.

Distributed generation options generally put out fewer emissions than traditional power plants. They are more environmentally friendly than traditional generation.

None of the distributed generation technologies has yet established itself as a source of high-quality power (2000). But all are in use, and are considered more reliable than grid power, or are used as able backups.

For Utah, encouraging distributed generation could be very beneficial. By standardizing grid interconnection processes, and by allowing retail markets to develop, Utah could encourage a more favorable environment for distributed generation. This may also help develop a market in Utah for microturbine and fuel cell technology. And the market is growing. In the U.S. distributed generation accounted for 4.2 billion dollars in revenues in 1998. The market is expected to grow by about 32 percent annually through 2003, at which time revenues are expected to reach about $16 billion in the U.S. By 2010, distributed generation is expected to make up 20 percent of generation capacity in the U.S.

Investment in distributed generation technology has increased by about $780 million in the last 6 years (National Energy Policy Commission 2001, 6-15). Investors clearly see distributed generation as being a growth technology, with a profitable future.

Costs associated with distributed generation are decreasing, making distributed generation a more realistic investment for Utah. The following table reveals interesting projections for the coming ten years. The typical size of on-site peaking capacity generators (microturbines, fuel cells, solar generators) will remain the same. However, the base-loaded generators built close to users will decrease in size by about 64 percent. This trend toward smaller generation capacity is demonstrated in the numbers of proposed small gas-fired power plants currently being authorized or constructed. Calpine, a leading operator and builder of gas-fired power plants has agreed to build small base-load capacity generators on-site for data campuses, who typically need more energy and higher-quality energy than residences and businesses hooked to the grid.

As power generation gets smaller and closer to home, the variable costs of generating power are expected to decrease 67 percent for peaking capacity and 69 percent for base-load capacity. Capital (fixed) costs will actually increase slightly (in absolute terms) for base-loaded capacity.

Characteristic	Generic peaking		Generic baseload	
	2000	2010	2000	2010
Typical size (megawatts)	0.4	0.4	2.5	1.6
Construction lead time (years)	0.2	0.2	0.5	0.5
Overnight costs (1999 dollars per kilowatt)				
Initial versions	—	700	—	2,000
Mature versions	531	440	591	560
Operating and maintenance costs				
Variable (1999 mills per kilowatthour)	23.0	15.5	15.0	10.4
Fixed (1999 dollars per kilowatt per year)	12.5	12.5	4.0	6.3
Heat rate (Btu per kilowatthour)	10,620	10,500	10,991	9,210
Source: Distributed Utility Associates, Assessing Market Acceptance and Penetration for Distributed Generation in the United States, June 7, 1999.				

A comparison of the costs of the various forms of distributed generation appears in the graph below.

Year	Photovoltaics	Fuel cell	Gas turbine	Gas engine	Gas microturbine
2000-2004					
Cost	7,870	3,282	1,555	1,320	1,785
Efficiency	14	38	22	29	27
2005-2009					
Cost	6,700	2,834	1,503	1,240	1,574
Efficiency	16	40	24	29	29
2010-2014					
Cost	5,529	2,329	1,444	1,150	1,337
Efficiency	18	43	25	30	31
2015-2020					
Cost	4,158	1,713	1,373	990	1,047
Efficiency	20	47	27	30	34
Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy and Electric Power Research Institute, Renewable Energy Technology Characterizations, EPRI-TR-109496 (Washington, DC, December 1997); and ONSITE SYCOM Energy Corporation, The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector (Washington, DC, January 2000).					

The prospects for implementing distributed generation on a broader scale are increasingly better as we approach the end of the projection (year 2020). While the current installed cost of a fuel cell generator is about $3282.00, which will decrease to $1713.00 by 2020. Microturbines experience a far smaller absolute and percentage change in installed costs over the next 20 years. This is possibly due to the current state of microturbine development as opposed to the development of fuel cells and photovoltaics. Microturbines represent a much more developed generation technology, so their costs can be expected to decrease more slowly than the emerging fuel cell and photovoltaic technologies.

Perhaps the best news apparent from the above chart is the increased projected efficiency associated with each of the distributed generation technologies as each technology develops. Efficiencies of solar distributed generation are expected to increase an average 12.3 percent every four years through 2020; fuel cell efficiency will increase 5.3 percent per four-year period over the same term; and efficiency for microturbines is expected to increase 8.04 percent every four-year period through 2020.

Further, increasing distributed generation capacity and efficiency actually reduces the load capacity being used, so that it can be exported or applied to growing areas in need of power. By encouraging distributed generation, Utah could increase its grid power surplus and leverage it to encourage industry development in Utah. A less burdened generation and transmission infrastructure means more power available to attract new business and industry.

Encouraging the market in Utah would require the following conditions be met:

- *Simplified interconnection standards:* Simple and equitable standards for interconnection with the grid would speed up approval times and remove the temporal barriers to distributed generation investment.
- *Growth in electricity demand:* As demand for electricity outpaces our ability to construct power plants, the supply shortage will boost demand for substitutes such as microturbines and fuel cells.
- *Efficient utility pricing schemes:* Pricing strategies must be more market-based. To accomplish this, the electric utilities industry must be restructured. Rather than guaranteeing a return on cost of service, a market-based return on quality of service should be implemented. This will force power companies to investigate higher quality options than large power plants.
- *Increased environmental protection:* Environmental restrictions on the siting and permitting of large power plants may decrease the incentive to build more traditional capacity, and cause suppliers and consumers alike to seek substitutes for traditional generation capacity and grid power.
- *Saturation of grid system and transmission capacity:* Utah can encourage growth in demand for alternate forms of energy by encouraging economic growth. In this sense, economic growth and electric power are endogenously related: it takes electricity to grow a state, but it takes state growth to stimulate demand for electricity. As demand for electricity outpaces our supply of electricity, new investments will be attracted to the quicker, cleaner, and often more cost-effective distributed generation option.

- *Dissatisfaction with grid power:* California's power crunch has led to blackouts and unpredictable power supplies. This has fueled demand in the distributed generation market since January. Utah should cultivate the perception that it has a stable and abundant supply of grid power. But as perceptions of grid power change, the market for alternatives will be more and more viable.
- *Technological improvement:* Utah can encourage the distributed generation market by encouraging development of alternate energies and micropower generation at its institutions.
- *Tax Credit:* Because distributed generation using renewable resources like solar and non-polluting or low-emissions technologies like fuel cells and microturbines creates a cleaner environment, their use should be encouraged. Grid power is dirtier to produce, besides being less fuel-efficient than most distributed generation technologies. Also, distributed generation decreases the burden on the grid, and also decreases power bottlenecking at transmission lines. The result is that users of distributed generation create a positive externality by generating their own power—greater transmissions and distribution efficiency and reliability for those who use the grid. Their production of this and the environmental externalities can be encouraged by offering users of distributed generation a tax incentive for having their own power systems and using them, especially during peaking hours.
- *Net Metering Legislation:* Currently, users of distributed generation have little incentive beyond productivity loss prevention and risk management to install on-site power. In fact, in most cases, distributed generation costs its users in backup or detachment fees (by which grid owners recoup their capital costs). These additional

costs beyond capital/installation/operation costs disincent the use of cleaner, more efficient power generation technology. These disincentives should be legislatively removed. Further, distributed generation often produces more power than is used on-site. For those users still attached to the grid, that excess power flows out onto the grid. In most states, the additional power provided to the grid is unrewarded—essentially, meters do not run backwards (or rather, are not allowed to). Especially in the West, provision of power to the grid should be encouraged, not discouraged. Utilities' political opposition to the reduction of the above mentioned disincentives should be tempered by the realization that if enough energy-intensive firms come to Utah (which is the goal of the state's Utah Silicon Valley Alliance), the bulk of grid customers will need distributed power systems, and may consider removing themselves from the grid completely, making the power companies less politically important anyway. A Net Metering bill would eliminate these disincentives, mandating that additional power provided to the grid by distributed generation users be reimbursed to the user by the power companies or the state.

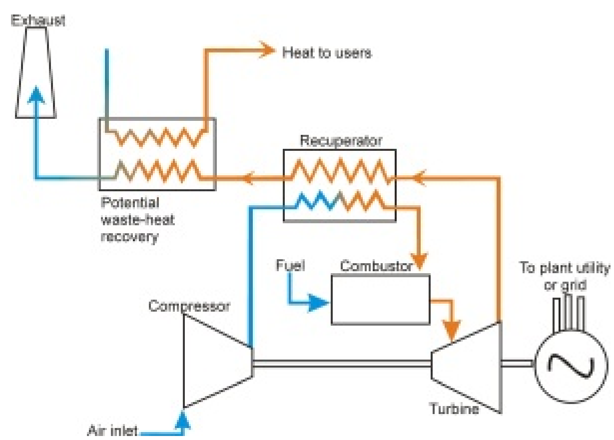
Microturbines

Small Distributed Generation

"The most important lesson from California's situation is that if businesses want to fix the energy problem, they have to take care of it themselves."

Jeff Byron
Director of Business Development for Calpine c-Power
In *CIO Magazine*, May 2001

The most developed, cost-effective, and currently marketable distributed generation technology is the microturbine. A stationary application of jet engine technology, microturbines can be operated with high levels of efficiency and low emissions. In general, the entire jet engine unit is about the size of a large refrigerator, but can generate between 25 and 500 kW of power.



The chart to the right demonstrates the microturbine combustion process. Natural gas is combusted in the combustor, which turns the turbine creating heat and electricity. The electricity is fed to the plant or appliance. Heat is recuperated and sent to a recovery mechanism, which can either distribute the heat to a user (e.g., a home or office heating unit) or send the heat back to the combustor, warming the air used in combustion and improving the efficiency of the combustion process. Emissions are sent out of the turbine unit through low-pollution exhaust system.

Benefits

Microturbines are not necessarily different from old-style diesel generators, which have generated power on-site for the last 40 years, in terms of electricity generation. Essentially, the microturbine has a higher wattage per pound, lower emissions per kW generated, and a higher level of efficiency to fuel used.

Microturbines offer the benefit of being smaller than old-style generators, too, which allows them to fit into building plans and existing structures without a lot of investment in construction. Their light weight makes it possible to add additional microturbine generators in a process called "ganging" without endangering the structural integrity of buildings.

Another benefit of microturbines is that they require very little maintenance, having few moving parts. Several manufacturers list low maintenance as the top benefit of purchasing microturbines versus other types of on-site generation.

Barriers

Like all distributed generation technologies, microturbines intend to make their users more independent of the imperfections of the grid. However, microturbine technology is not developed enough to offer truly high-quality power. Their reliability is no better than the grid (99 percent when running continuously for 4000 hours), making ganging microturbines a security necessity, especially if users want to detach completely from the grid (Tanner 2000). Backups for backup generators are not generally cost-effective, and their necessity is a barrier to microturbine market expansion, indeed to all distributed generation expansion. Reliability is probably the least difficult problem for microturbine developers to solve.

Microturbines face two other challenges—interconnection with the grid and costs. Interconnection of microturbines with the grid faces the same challenges as all distributed generation. The pricing and political aspects of these challenges were treated in some detail in a previous section. However, the technical aspects bear further analysis.

Technically, interconnection of microturbines with the grid presents problems with grid operators, who cannot monitor how much power is being supplied to the grid, and cannot accept continuous power being supplied from distributed sources to the grid because the power may be dangerous if it gets on to the grid. For example, when transmission and distribution wires are shut down for maintenance, it would be disastrous for a continuously generating microturbine to be running any excess capacity, since the extra power would flow out onto the grid and possibly injure or kill maintenance workers.

Technologies that aid interconnection and that can be controlled by grid operators are currently being developed, but are not solutions to the interconnection problem as yet.

Chuck Tanner, a vice president at Capstone Microturbines, reports that the costs of microturbines are a major restraint on the emergence of a large market for distributed generators: "For large-scale acceptance the cost must be in the range of reciprocating engines, i.e., $400.00-600.00 per kilowatt," (2000). Currently, microturbine units cost about \$1100.00 per kW of capacity, making them the cheapest high-tech, clean distributed generation technology on the market. Because they are more efficient that reciprocating engines, microturbines also reach economies of scale more quickly than other distributed generation technologies, and offset the capital costs by providing power more efficiently (Tanner 2000).

End use efficiency improvements (i.e., improving the efficiency of manufacturing processes, electrical appliances, etc.) could be an important development for increasing the viability of microturbines and other distributed generation technologies, because they decrease the amount of generation capacity that needs to be purchased, operated, and maintained.

Technology	2000-2004		2005-2009		2010-2014		2015-2020	
	Cost (1998 Dollars per Kilowatt)	Efficiency (Percent)	Cost (1998 Dollars per Kilowatt)	Efficiency (Percent)	Cost (1998 Dollars per Kilowatt)	Efficiency (Percent)	Cost (1998 Dollars per Kilowatt)	Efficiency (Percent)
PV	5,529	14	4,158	16	3,178	18	2,426	20
Fuel Cell	3,625	40	3,000	40	2,425	40	1,725	40
Gas Turbine	900	29	900	29	900	29	900	29
Gas Engine	900	35	900	35	900	35	900	35
Gas Microturbine	800	27	700	27	700	27	700	27
Conventional Oil	500	33	500	33	500	33	500	33

Above, the projected costs of distributed power systems through the year 2020 are reported in a table (table from "Modeling Distributed Electricity Generation in NEMS Buildings Models," by Boedecker, Cymbalsky, & Wade 1998). The table demonstrates that the cost in 1998 dollars per kW generated by a microturbine is not anticipated to sink below \$700.00. However, except for old conventional oil technology, in use for over half a century, microturbines are the least costly options. Of course, the efficiency is not as high as fuel cells and large gas turbines. But, higher efficiencies—up to 60 percent—have been obtained in tests of cogenerating, recuperating engines. Therefore, microturbines may represent the most efficient and least costly distributed generation technology in the next 20 years, beginning in the year 2005.

Microturbines, as alternate energies go, is very cost-efficient. Photovoltaics (PV) or solar cell power systems are not projected to compete with microturbines in terms of cost. Fuel cells will still be very expensive, though the efficiency estimate (40 percent) given above is conservative, and higher efficiencies may justify the cost per kW of capacity.

Despite their cost and backup drawbacks, microturbines offer users the benefit of about 6,000 hours of continuous generation per year (for a 250 kW unit, 1.5 million kilowatt hours). For users who desire only peak-shaving generation—running a generator during peak hours to avoid paying peak-hour prices—and backup generation, microturbines would be needed for less than 1000 hours per year. The less users employ microturbines' capacity, the less cost-efficient they are.

Microturbines are facing some tough challenges—robustness, interconnection with the grid and costs.

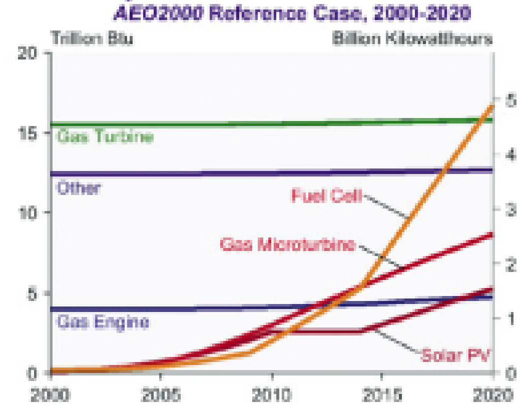
Regarding robustness there has been steady improvement. An endurance test of a Capstone Model 330 has now logged more than 4000 hours and has had more than 99% availability. Still more can be done and will be done. This is probably the least difficult challenge.

Microturbines can achieve greater fuel efficiencies through two processes called recuperation and cogeneration, respectively. Recuperated microturbines have a sheet metal heat exchanger that takes heat from the exhaust stream and uses it to heat the air entering the microturbine’s intake system. With hot air coming being used in combustion, combustion of natural gas is more efficient, and recuperated microturbines are 30-40 percent more fuel-efficient than unrecuperated systems.

Likewise, cogeneration is a process by which heat is taken from the microturbine’s exhaust stream and is used to heat water to produce steam, which can be used to turn other turbines. Cogeneration technology, because of microturbines’ lower heat output than traditional gas-fired turbines, is not well developed, but exists.

Market Projections

Figure 2. Buildings Sector Electricity Generation by Selected Distributed Resources in the *AEO2000* Reference Case, 2000-2020



Source: AEO2000 National Energy Modeling System, run AEO2K.D100199A.

Despite development and the other drawbacks assessed above, microturbines will be an expansive market in the future. The market for microturbine products will be a significant niche, totaling $2.4 billion to $8 billion by 2010; and more than 50 percent of that market will be international (Chief Engineer 2001). A study conducted by GRI projects that, while initial sales of microturbines will occur primarily in North America, more than 50 percent of sales will be international by 2010. Many industry stakeholders project that microturbines will provide 8% of the estimated 1 million megawatts (MW) of new power capacity that will be needed by 2010 (2001).

The short-run reliability of the grid in the western U.S. is expected to decrease, as new users are added and power-intensive industry expands, with no concurrent construction of grid or generation capacity. Therefore, the short-run market for microturbines is also robust, because backup systems have become essential to the new high-tech economy.

The graph on the preceding page (taken from Energy Information Service 2000) demonstrates that microturbines will account for about 2.5 billion kW generated in new construction in the year 2020, and the employment of microturbines is increasing at that point. While microturbines do not have as optimistic a long-term outlook as fuel cells, which will account for about five billion of the kW generated in new construction in 2020, overtaking traditional gas turbines, they are the most viable alternative power generation system in new construction until about 2013.

Microturbine Industry

An analysis of the specific companies involved in microturbine manufacturing and development follows.

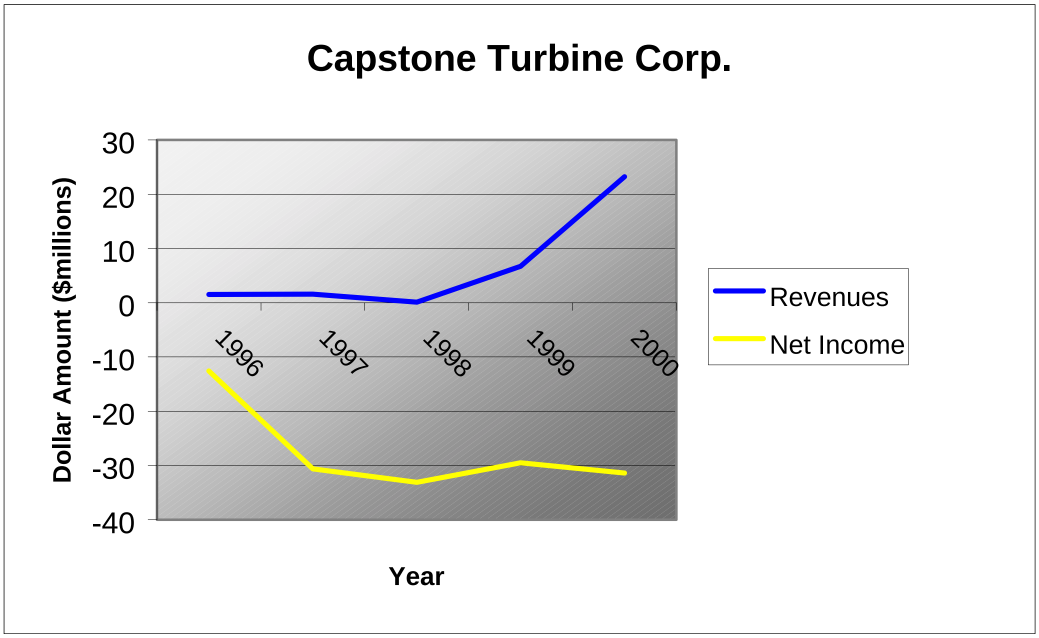
Capstone Turbine Corporation

Capstone is recognized as the world's leader in microturbine sales and technology. They have perfected a recuperating engine that achieves higer efficiencies than any other on the market.

Capstone's most recent financial reports show that the company lost about $23 million last year, though their revenues are growing at 32 percent per year. Financial and contact information follows.

Capstone Turbine Corp.
21211 Nordhoff St.
Chatsworth, CA 91311
Los Angeles City Guide
Phone: 818-734-5300
Fax: 818-734-5320
http://www.microturbine.com

Financial Information



2000 Sales (mil.): $23.2
1-Yr. Sales Growth: 246.3%
2000 Net Inc. (mil.): ($31.4)
2000 Employees: 223
1-Yr. Employee Growth: 32.0%
Market Capitalization: 2,596,997,510

Capstone Turbine Corporation

Sector:	Manufacturing
Industry:	Manufacturing - Turbines, Transformers & Other Electrical Generation Equip.
Nasdaq	CPST

Detailed Annual Financials

Income Statement

All dollar amounts in millions except per share amounts.	Dec-00	Dec-99
Revenue	23.2	6.7
Cost of Goods Sold	27.8	15.7
Gross Profit	(4.6)	(9.0)
Gross Profit Margin	--	--
SG&A Expense	35.4	20.4
Operating Income	(40.0)	(29.4)
Operating Margin	--	--
Nonoperating Income	9.5	0.5
Nonoperating Expenses	0.9	0.7
Income Before Taxes	(31.4)	(29.5)
Income Taxes	0.0	0.0

Net Income After Taxes	(31.4)	(29.5)
Continuing Operations	(31.4)	(29.5)
Discontinued Operations	0.0	0.0
Total Operations	(31.4)	(29.5)
Total Net Income	(31.4)	(29.5)
Net Profit Margin	--	--
Diluted EPS from Continuing Operations ($)	(12.82)	(24.53)
Diluted EPS from Discontinued Operations ($)	0.00	0.00
Diluted EPS from Total Operations ($)	(12.82)	(24.53)
Diluted EPS from Total Net Income ($)	(12.82)	(24.53)
Dividends per Share	0.00	0.00

Balance Sheet	Dec 00	Dec 99
Cash	236.9	6.9
Net Receivables	3.7	2.4
Inventories	14.1	8.8
Other Current Assets	1.7	2.2
Total Current Assets	256.4	20.3
Net Fixed Assets	11.6	7.9
Other Noncurrent Assets	34.0	8.7
Total Assets	302.0	36.9
Accounts Payable	4.7	1.7
Short-Term Debt	1.5	1.4
Other Current Liabilities	12.1	10.9
Total Current Liabilities	18.3	14.0
Long-Term Debt	4.0	4.5
Other Noncurrent Liabilities	0.3	6.2
Total Liabilities	22.6	24.7
Preferred Stock Equity	0.0	156.5
Common Stock Equity	279.4	(144.2)
Total Equity	279.4	12.3
Shares Outstanding (mil.)	75.8	2.4

Cash Flow Statement	Dec 00	Dec 99
Net Operating Cash Flow	(23.8)	(24.5)
Net Investing Cash Flow	(26.9)	(5.2)
Net Financing Cash Flow	280.8	31.6
Net Change in Cash	230.1	1.9
Depreciation & Amortization	7.1	2.4
Capital Expenditures	(10.1)	(2.4)
Cash Dividends Paid	0.0	0.0

MEDIA GENERAL FINANCIAL SERVICES

Some financial information provided by Media General Financial Services, Inc., Richmond, Virginia

Sales Analysis

Sales were up sharply during the first quarter of 2001 versus the previous year's first quarter. During the first quarter of 2001, sales at Capstone Turbine totaled $8.91 million. This is an increase of 137.7% from the $3.75 million in sales at the company during the first quarter of 2000. During the previous 8 quarters, sales at Capstone Turbine have increased compared with the same quarter in the previous year.

Sales increased substantially in 2000: During the year ended December of 2000, sales at Capstone Turbine were $23.16 million. This is an increase of 246.0% versus 1999, when the company's sales were $6.69 million.

Profitability Analysis

In 2000, earnings before extraordinary items at Capstone Turbine were -$31.42 million, or -135.7% of sales. This profit margin is an improvement over the level the company achieved in 1999, when the profit margin was -441.1% of sales. The company has reported losses before extraordinary items for each of the past 5 years.

The company's return on equity in 2000 was -11.5%. This was significantly better than the -282.0% return the company achieved in 1999. (Extraordinary items have been excluded).

(Source for Corporate Information. 2001. *Research Report: Capstone Turbine Corp.* http://profiles.wisi.com/profiles/scripts/corpinfo2.asp?cusip=14067D102. June 7, 2001)

Top Officers

President, CEO, and Director: Mr. Ake Almgren, age 54, $425,000 pay
SVP, Finance & Administration, CFO, and Secretary: Mr. Jeffrey Watts, age 50, $160,000 pay
SVP, Strategic Technology Development: Mr. William Treece, age 60, $150,000 pay
SVP, Engineering: Mr. Paul Chancellor
VP, Marketing: Mr. Mark Kuntz
VP, Power Electronics Group: Mr. Joel Wacknov
VP, Quality: Mr. Daniel Callahan
VP, Supply Management: Mr. Lloyd Kirchner
VP, Business Development & Sales, Canada : Mr. Richard Carryer
VP, Energy Service Provider Sales: Mr. Douglas Condon
VP, Business Development: Harol Koyama
VP, Human Resources: Mr. Dominic A. Lucenta

VP, Original Equipment Manufacturer Sales: Mr. David McShane
VP, Distributor Sales: Mr. Kevin Young
Director, Operations: Mr. Paul Berner
President, Capstone California: Mr. Michael Tingus
Controller: Mr. David Duckhorn

Stock

NASDAQ: CPST

(Hoovers. 2001. Capstone Turbine Corp.), (Corporate Information. 2001. Capstone Turbine Corp.)

Elliott Turbomachinery Co., Inc., Ebara Group

Elliott is a subsidiary of the Ebara Group, which makes turbo engines for mostly Japanese Customers. Elliott was acquired by Ebara in March of 2000. Elliott is not a growth company. We do not recommend that Utah pursue their business.

Elliott Turbomachinery Co., Inc., Ebara Group
901 North Fourth Street
Jeannette, PA 15644-1473 USA
Phone: (724) 527-2811
Fax: (724) 600-8442
info@elliott-turbo.com
http://www.elliott-turbo.com/new/index.html

Top Officers

President and CEO - David Assard

Ebara Group

Ebara Group
11-1 Haneda Asahi-cho, Ohta-ku
Tokyo 144-8510, Japan
Phone: +81-337436111
Fax: +81-337453356
http://www.ebara.co.jp

Financial Information

2000 Sales (mil.): $4,310.4
1-Yr. Sales Growth: (7.9%)
2000 Net Inc. (mil.): $52.6
2000 Employees: 13,442
1-Yr. Employee Growth: 1.6%

Top Officers

Chairman and Representative Director: Mr. Hiroyuki Fujimura
VC and Representative Director: Mr. Shigeru Maeda
President and Representative Director: Mr. Masatoshi Yoda
EVP and Representative Director: Mr. Yukio Ikeda
Senior Managing Director; Group Executive, Environmental Engineering Group: Mr. Isao Toyooka
Senior Managing Director; Group Executive, Machinery and Equipment Group: Mr. Koichi Matsuura
Senior Managing Director; Group Executive, Precision Machinery Group: Mr. Yukio Shiozawa
Managing Director; Deputy Group Executive, Environmental Engineering Group: Mr. Tsuyoshi Hirota
Managing Director; Executive General Manager, Osaka Office: Mr. Masayuki Izawa
Managing Director; Deputy Group Executive, Environmental Engineering Group: Mr. Shiro Nagato
Managing Director; Group Executive, Corporate Group: Mr. Toshihiro Katagiri
Managing Director; Deputy Group Executive, Machinery and Equipment Group: Mr. Nobutaka Eda
Managing Director; Deputy Group Executive, Environmental Engineering Group: Mr. Shigemi Sekine
Managing Director; Deputy Group Executive, Machinery and Equipment Group: Mr. Fumio Shimakawa

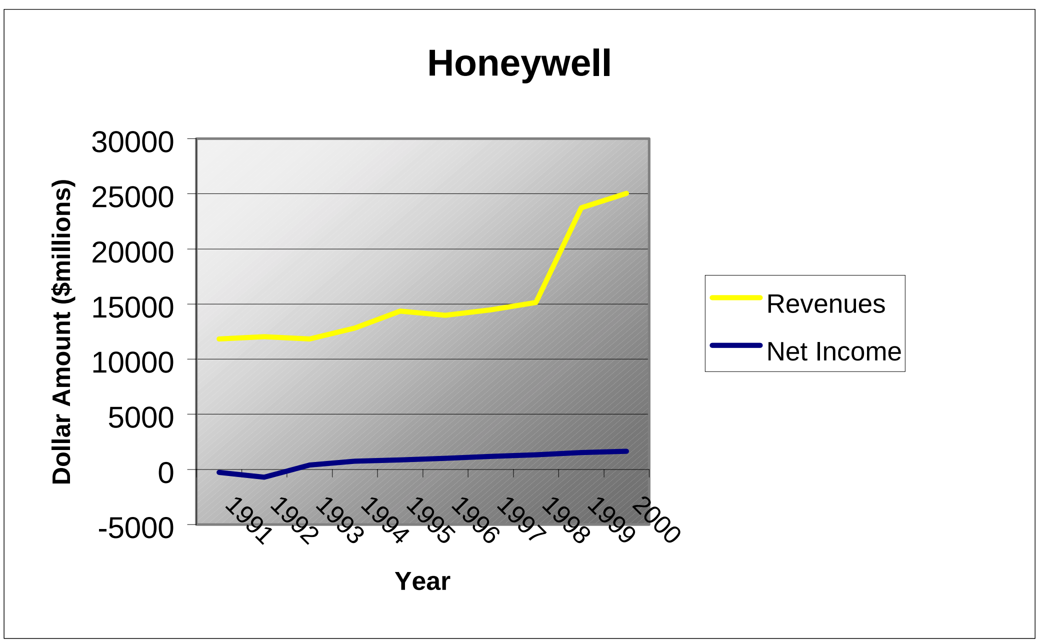
Managing Director; Executive General Manager, International Business, Environmental Engineering Group and Group Executive, China Operations Group: Mr. Kazuyoshi Terashima
(Hoovers. 2001. Ebara Corporation.)

Honeywell Power Systems

Honeywell Power Systems, manufacturers of the Parallon 75 microturbine, are world leaders in the aviation systems and manufacturing industry. Microturbines and alternative power systems do not make up a major portion of Honeywell's overall revenues, although they are a major vendor of distributed generation because of their large customer base from other products. We do not recommend Utah pursue Honeywell, since they are well established in their other U.S. locations and do not show signs of wanting to relocate, not to mention that their operations are huge and would be far too costly to move and they are heavily manufacturing-oriented.

Honeywell Power Systems
101 Columbia Rd., PO Box 4000
Morristown, NJ 07962-2497
Phone: 973-455-2000
Fax: 973-455-4807
Toll Free: 800-707-4555
http://www.honeywell.com
http://www.parallon75.com/#

Financial Information



2000 Sales (mil.): $25,023
1-Yr. Sales Growth: 5.4%

2000 Net Inc. (mil.): $1,659
1-Yr. Net Inc. Growth: 7.7%
2000 Employees: 125,000
1-Yr. Employee Growth: 4.2%
Market Capitalization: 39,144,945,188

Top Officers

Chairman and CEO: Mr. Michael R. Bonsignore, age 60 (prior to promotion)
COO and EVP, Aerospace: Mr. Robert D. Johnson, age 53
COO and EVP, Diversified Businesses: Mr. Giannantonio Ferrari, age 61
SVP and CFO: Mr. Richard F. Wallman, age 50
SVP and General Counsel: Mr. Peter M. Kreindler, age 56
SVP, Chief Technology Officer: Mr. Barry C. Johnson, age 57
SVP and Chief Administrative Officer: Mr. James T. Porter, age 49
SVP, Human Resources and Communications: Mr. Donald J. Redlinger, age 56
VP and Chief Information Officer: Mr. William L. Sanders
VP and Secretary: Ms. Kathleen M. Gibson
VP and Treasurer: Mr. James V. Gelly
VP and Controller: Mr. Richard J. Diemer Jr.
VP and General Manager, Honeywell Aircraft Landing Systems: Ms. Adriane M. Brown
VP, Government Relations: Mr. Kenneth W. Cole
VP, Health, Safety, Environment, and Remediation: Mr. Jay B. Stephens
VP, Investments: Mr. Edward T. Tokar
VP, Six Sigma and Productivity: Mr. Raymond C. Stark
President, Honeywell Aerospace Services: Mr. James D. Taiclet Jr., age 40
President, Commercial Aviation Electronic Systems: Mr. Francis W. Daly
President, Electronic Materials: Mr. Marijn E. Dekkers
President, Home and Building Control Products: Mr. Albrecht Weiss
President, Honeywell Aerospace Electronic Systems: Mr. Michael A. Smith, age 57
President, Honeywell Consumer Products Group: Mr. David E. Berges, age 51
President, Honeywell Electronic Materials: Mr. Mohsen Sohi
President, Honeywell Engines and Systems: Mr. Steven R. Loranger, age 49
President, Honeywell Federal Manufacturing and Technologies: Ms. Karen K. Clegg
President, Honeywell Industrial Control and Friction Materials: Mr. John H. Weber, age 45
President, Performance Chemicals and Polymers: Mr. Dean Flatt, age 51
President, Polymers: Mr. David N. Weidman
President, Solutions and Services Business, Home and Building Control: Mr. J. Kevin Gilligan
President, Specialty Chemicals: Mr. Gary A. Cappeline
President, Turbocharging Systems: Mr. Jeffrey I. Sinclair
President, Transportation and Power Systems: Mr. Eduardo Castro-Wright
President, Europe: Mr. Willi Loose
President, Latin America: Mr. Alain Monie

Stock

NYSE: HON

(Hoovers. 2001. Honeywell.), (Corporate Information. 2001. Honeywell.)

Pratt & Whitney (A division of United Technologies)

Pratt & Whitney (A division of United Technologies)
400 Main St.
East Hartford, CT 06108 (Map)
Phone: 860-565-4321
Fax: 860-565-5442
http://www.pratt-whitney.com

Financial Information

2000 Sales (mil.): $7,366
1-Yr. Sales Growth: (4.0%)
2000 Employees: 30,000

Top Officers

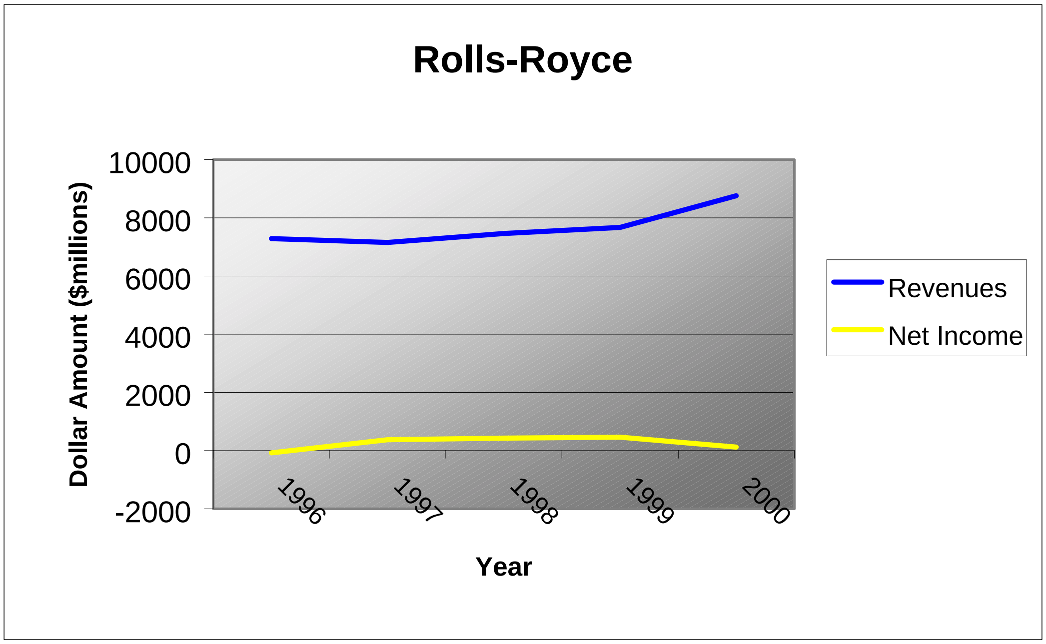
President: Mr. Louis R. Chênevert
EVP and COO: Mr. Robert Leduc
SVP, Engineering: Mr. D. Edward Crow
SVP, Finance: Mr. Jothi Purushotaman
SVP, Module Centers and Operations: Mr. Robert Ponchak
Chairman, Pratt & Whitney Canada: Mr. L. David Caplan

President, CEO, and COO, Pratt & Whitney Canada: Mr. Gilles P. Ouimet
VP and CIO: Mr. Peter F. Longo
VP and General Counsel: Mr. Paul Beach
VP, Environment, Health and Safety, and Medical: Ms. Claudia Coplein
VP, Quality: Mr. Joseph Lubenstein
VP, Strategic Planning: Mr. John Sibson
VP, Human Resources and Organization: Mr. John Leary
Acting VP, Communications: Mr. Gary Minor
President, Aftermarket Services: Mr. James Robinson
President, Military Engines: Mr. Stephen N. Finger
President, Space and Russian Programs: Mr. Larry Knauer
President, Power Systems: Ms. Ellen S. Smith
(Hoovers. 2001. Pratt & Whitney.)

Rolls-Royce

Rolls-Royce is perhaps Utah's only connection to the microturbines market, and it is a tenuous connection at that. Rolls-Royce manufactures and designs gear systems at its Park City operation in Summit County, UT, and that facility is currently being expanded. It may be feasible to ask Rolls-Royce to bring their power systems division to Utah, simply because they enjoy their relationship with Utah, and are already doing business in the state. Utah needs a presence in alternative energy, and has very few alternative energy companies—Rolls-Royce is not known as a manufacturer of power systems, but could serve as an anchor for a future alternative energy and distributed generation development industry in Utah.

Rolls-Royce
65 Buckingham Gate
London SW1E 6AT, United Kingdom
Phone: +44-20-7222-9020
Fax: +44-20-7227-9178
http://www.rolls-royce.com



2000 Sales (mil.): $8,753
1-Yr. Sales Growth: 14.1%
2000 Net Inc. (mil.): $124
1-Yr. Net Inc. Growth: (73.0%)
2000 Employees: 46,600
1-Yr. Employee Growth: 13.9%
Market Capitalization: 5,461,018,111

Top Officers

Chairman: Sir Ralph H. Robins, age 68
Chief Executive: Mr. John E. V. Rose, age 47
COO; President Civil Aerospace: Mr. John Cheffins
President and CEO, Rolls-Royce North America: Mr. James M. Guyette, age 55
President, Marine Business: Mr. Saul Lanyado
Engineering and Technology Director: Mr. Philip C. Ruffles, age 60
Finance Director: Mr. Paul Heiden, age 43
Group Marketing Director: Mr. Richard T. Turner, age 57
Operations Director; President Defence Aerospace: Mr. Colin H. Green, age 51
Company Secretary: Mr. Charles E. Blundell, age 48
Managing Director, Airlines Business: Mr. Mike Terrett
Managing Director, Defence (Europe): Mr. Andy Stevens

Stock

RYCEY

(Hoovers. 2001. Rolls-Royce.), (Corporate Information. 2001. Rolls Royce.)

Rolls-Royce North America
14850 Conference Center Dr.
Chantilly, VA 20151
Phone: 703-834-1700
Fax: 703-709-6086

Top Officers

President and CEO: Mr. James M. Guyette, age 55
EVP, Government Business: Mr. Mike Ryan
SVP, Government Relations: Mr. Ed Pease
VP and General Counsel: Mr. Tom Dale
VP, Corporate Communications: Ms. Mia Kelly Walton
VP, Finance, Sales, and Treasurer: Ms. Gale Niemi
VP, Human Resources: Ms. Rebecca Blackman
(Hoovers. 2001. Rolls-Royce North America.)

FUEL CELLS

Engine of the Hydrogen Economy

"The Stone Age did not come to an end because we had a lack of stones, and the oil age will not come to an end because we have a lack of oil."

Sheikh Yamani
Former Saudi Oil Minister

EXECUTIVE SUMMARY

Energy has always been at the forefront of our national concerns, but never more so than now. With blackouts and brownouts assured in California for the second straight summer, and an impending energy crisis in the Eastern United States, the topic of energy has become as hot as the temperature outside. Fuel cells offer a compelling solution to our energy needs by using the most abundant mineral in the universe to generate electricity.

Fuel cells generate electricity using a stream of electrons produced by the splitting of hydrogen protons and electrons. The "waste product" of fuel cells is pure water. The worldwide market for fuel cells is expected to be $2.3 billion by 2005[1] but only of the cost decreases significantly. The high cost of fuel cells can be attributed to lack of demand and lack of an efficient way to produce and store hydrogen to power the fuel cell.

Utah has a small but somewhat paltry presence in the fuel cell industry. Utah has a good academic resource, but local companies have not developed the type of network that is required for the State to be a leader in the development of fuel cells.

FINDINGS

• Fuel cells generate electricity, using hydrogen as the fuel. Hydrogen is the most abundant element on earth.

• Fuel cells are 30 – 90 percent efficient, much greater than the internal combustion engine running on gasoline.

[1] Business Communications Company

• Fuel cells can allow power generation independent of the power grid.

• Fuel cells are too expensive to achieve mainstream adoption in the market. Costs cannot come down until production increases, production cannot increase until demand increases through lower costs, and the cycle continues.

• Most of the processes to make hydrogen consume more energy than is eventually available in the hydrogen. Although fuel cells are efficient, an efficient way to produce and store hydrogen has yet to be developed.

• Distributing hydrogen to consumers for use in fuel cells will require a whole new infrastructure.

• Commercialization of fuel cells is being driven by coalitions comprised of fuel cell developers, oil companies, automakers, government agencies, and academic institutions.

• Utah has a small presence in the fuel cell industry and is not part of any major coalition or industry group.

• Utah's fuel cell companies have a technology development focus, but not a product-oriented marketing focus.

RECOMMENDATIONS

• **Olympic Technology Expo –** The Olympics will be a great opportunity to showcase Utah's technologies to the world. By hosting a Utah Technology Expo, little known and ignored companies could have the opportunity to gain some exposure and possibly make contacts with the various business leaders from around the world that will be attending the Games.

• **Application-Specific Fuel Cell Development –** Encourage Utah companies to develop application-specific, market-ready products by contracting with these companies to develop efficient energy applications for small state infrastructure projects (lights, road signs, etc.) Fuel cells are perfect for remote areas far from the electric power grid. This is an opportunity for rural, isolated areas to generate the power necessary for things like Smart Sites and other energy-intensive facilities. By challenging the companies to develop market-ready products, the State can simultaneously encourage the companies to adopt a market focus, while at the same time solving some of its own energy concerns.

• **Focus Funds in Hydrogen Research –** The State needs to be very strategic in its appropriation of funds for research. Efficient production and storage of hydrogen continues to be the greatest hindrance to the commercialization of fuel cells. Currently, the most efficient (yet relatively inefficient) process for obtaining hydrogen is the reformation of methane. Methane can be produced from coal, of which Utah has a large amount.

No company, state, or nation has yet to become the leader in hydrogen development. The potential growth and economic benefits to the region that develops hydrogen efficiently will, by comparison, far exceed that of the OPEC nations.

• **Make Utah a Test Site for Fuel Cell Vehicles –** The State and its universities already have some ties to the auto industry. Utah needs to leverage these relationships to encourage the mass testing of fuel cell commercial passenger vehicles in the State. For instance, Utah has the famous Bonneville Salt Flats that could be used for a Fuel Cell speed record contest between fuel cell car developers.

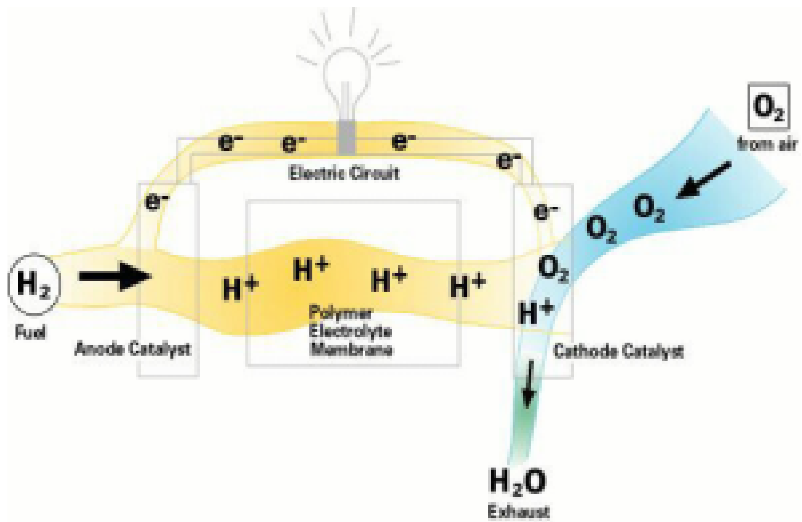
• **Convert All State Fleets to Fuel Cells –** The quickest way to gain the attention of the fuel cell industry is to become one of its largest customers. As has been pointed out, costs can only come down if there is more production, and there cannot be production without demand. The example of SunLine Transit in California shows that such a bold move has the potential to make an organization a leader overnight. If UDOT converted all of its fleet to fuel cells, Utah would instantly attract the attention of the whole industry. The State can then partner with other companies to develop the hydrogen production/refueling infrastructure to make Utah the first region in the world where the general public drives vehicles powered by fuel cells.

• **Alternative Fuel Policy –** Just as California has created excitement in the industry, and demand in the market, with its policy to have 10 percent of California cars be zero-emissions in 2003, Utah could facilitate commercialization of fuel cells by making similar requirements. By talking about it and advocating it, Utah can become a major center for fuel cell development - something that will be attractive to many companies seeking to produce fuel cells *en masse* in five to ten years.

WHAT IS A FUEL CELL?

A fuel cell is a device that uses hydrogen to generate electricity and expels water as a waste product. In **Figure 1**, the principle of a fuel cell is demonstrated. Hydrogen is introduced to the anode of the fuel cell where a catalyst encourages the hydrogen to split into an electron and a proton. The proton and the electron each take different paths to the cathode where they are rejoined along with oxygen to form water. The proton passes through an electrolyte on its way to the cathode. The key to a fuel cell is that the stream of electrons forms a current that can be utilized (electricity) before it rejoins the hydrogen protons and oxygen.

Figure 1



Source: Fuel Cells 2000

The operation of a fuel cell resembles that of a battery. Unlike a battery, however, a fuel cell does not require recharging. Fuel cells produce electricity in an electrochemical reaction involving simple elements hydrogen and oxygen. In this case the hydrogen is the "fuel" that the fuel cell uses to make electricity. Fuel cells can also utilize fuels containing hydrogen, including methanol, ethanol, natural gas, and even gasoline or diesel fuel. Fuels containing hydrogen generally require a “fuel reformer” that extracts the hydrogen.[2] As long as the fuel and oxygen is supplied to the cell it will produce electricity unceasingly.

Fuel cells can be made in a variety of sizes. They can be used to produce small amounts of electric power, for devices such as portable computers and radio transmitters, or large quantities of power for electric power stations. Since the fuel cell relies on chemistry and not combustion, emissions from this type of a system would still be much smaller than emissions from the cleanest fuel combustion processes.[3]

BRIEF HISTORY

The first fuel cell was developed by a Welsh-born lawyer/chemist named Sir William Robert Grove in 1839. Grove realized that if electrolysis, using electricity, could split water into hydrogen and oxygen then the opposite would also be true. Combining hydrogen and oxygen, with the correct method, would produce electricity. To test his reasoning, Sir William Robert Grove built a device that would combine hydrogen and oxygen to produce electricity, the world's first gas battery, later renamed the fuel cell. His invention was a success, and Grove's work advanced the understanding of the idea of

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[2] KPMG Project Report. *Estimated Economic Impacts and Market Potential Associated With the Development and Production of Fuel Cells in British Columbia*. March 1996
[3] Fuel Cells 2000 – www.fuelcells.org 5/2/01 10:50 am

conservation of energy and reversibility. Interest in Grove's "gas battery" diminished as the dawn of cheap fossil fuels approached and the soon to be discovered steam engine captivated the present day society.

Interest in the fuel cell as a practical generator did not begin until the 1960's, when the U.S. space program chose fuel cells over riskier nuclear power and more expensive solar energy. Fuel cells furnished power for the Gemini and Apollo spacecraft, and still provide electricity and water for the space shuttle.

NASA and the space program provided fuel cells with the initial research and development the technology required. Since their adoption by the space program, fuel cell technology has achieved widespread recognition by industry and government as a clean energy source for the future. Eight of the ten largest companies in the world are involved with fuel cells in some respect.[4]

BENEFITS OF FUEL CELLS

> *"Fuel cells can provide major environmental, energy and economic benefits that advance critical national goals: clean air, increased national self-reliance for transportation fuels, and enhanced national security."*
>
> *Powering the New Economy - Energy Accomplishments, Investments, Challenges,*
> U.S. Department of Energy,
> September 27, 2000.

The benefits of fuel cells cover a wide range of economic, environmental, and national security issues. The following list of benefits is based on analysis by Fuel Cells 2000, and the FuelCellStore.com:

Economic Growth

If one percent of the global vehicle market, 450,000 vehicles, were powered by fuel cells it would constitute a $2 billion market. The consulting firm Arthur D. Little projects that if 20 percent of cars used fuel cells, 800,000 jobs would be created. Fuel cells could create new markets for steel, electronics, electrical and control industries and other equipment suppliers.

In addition, fuel cells provide a way to reach markets in developing nations and provide power to previously unreachable domestic regions.

> *"Deregulation and fuel cells have opened the opportunity for distributed generation plants. Distributed generation is the industry term for generating electricity at the place where the electricity is to be used.*

[4] Fuel Cell Store – www.fuelcellstore.com 5/29/01 2:00pm

Distributed generation avoids the enormous capital costs, underutilization of plant assets and transmission losses associated with a centralized distribution system that is the current model for the utility grid."

Source: fuelcellstore.com

Fuel cells do not have to be "connected" to anything. In the presence of hydrogen and oxygen, a fuel cell could produce electricity in the most remote place on earth. This aspect of fuel cells is especially applicable to Utah's Smart Site initiative and other initiatives aimed at promoting rural high-tech economic development. Whereas wireless technology facilitates the expansion of bandwidth, distributive generating capabilities such as fuel cells could supply the essential power to high-energy consuming technology facilities.

Energy Security

"The most urgent, long-term security requirement for the United States is to reduce our dependence on imported oil by developing clean, safe, renewable energy systems, and energy conservation programs."

Rear Admiral Eugene Carroll, US Navy, Retired, Deputy Director, Center for Defense Information

U.S. energy dependence is higher today than it was during the "oil shock" of the 1970's, and oil imports are projected to increase. Passenger vehicles alone consume 6 million barrels of oil every day, equivalent to 85% of oil imports.

The following is a summary of the US oil problem:

- Since 1992, U.S. oil production is down 17%, consumption is up 14%.
- Imports are now at 56% and growing rapidly.
- In 1973 (Arab Oil Embargo) the U.S. imported 35% foreign oil.
- DOE predicts 65% foreign oil dependence by 2020
- At current prices, the U.S. spends $300 million per day on imported oil, which amounts to over $100 billion per year on foreign oil--one-third of total trade deficit.
- Iraq is the fastest growing source of U.S. oil imports

Source: Senator Murkowski website - www.senate.gov/~murkowski

Clean and Efficient

Hydrogen, the fuel in fuel cells, is the most abundant element in the universe. A fuel cell enables a stream of electrons from hydrogen atoms to make an electric current and then combines the hydrogen with oxygen to make water as the "waste product." In its purest form a fuel cell doesn't "consume" fuel, rather, it manipulates chemical properties of the hydrogen atom to generate electricity.

The U.S. Department of Energy projects that if 10% of automobiles nationwide were powered by fuel cells, regulated air pollutants would be cut by one million tons per year and 60 million tons of the greenhouse gas carbon dioxide would be eliminated.

Figure 2 demonstrates a comparison of the water vapor and carbon monoxide emissions from fuel cells, running on a variety of fuels, as compared to an internal combustion engine.

<u>Figure 2</u>

Engine Type	Water Vapor/mile	Carbon Dioxide/mile
Gasoline Combustion	0.39 lb.	0.85 lb.
Fuel Cell Running on Hydrogen from Gasoline	0.32 lb.	0.70 lb.
Fuel Cell Running on Hydrogen from Methane	0.25 lb.	0.15 lb.
Fuel Cell Running on Renewable Hydrogen	0.25 lb.	0.00 lb.

Courtesy of Jeremy Snyder, Desert Research Institute

"By converting fuel directly into energy through an electrochemical reaction, fuel cells extract more power out of the same quantity of fuel when compared to traditional combustion. This direct process results in a reduced amount of fuel being consumed and greater efficiencies, 30% to 90%, depending on the fuel cell system and if the surplus heat is utilized. Combustion-based energy generation first converts the fuel into heat, limited by Carnot's Law of Thermodynamics, and then into mechanical energy, which provides motion or drives a turbine to produce energy. The additional steps involved in combustion generation allow energy to escape as heat, friction and conversion losses, resulting in lower overall efficiencies."

Source: fuelcellstore.com

Fuel Flexibility

Fuel cells are capable of operating on hydrogen, or hydrogen reformed from any of the common fossil fuels available today.

High Power Densities

The amount of power a fuel cell can generate within a given volume is usually given in kWh/liter. These numbers continue to rise as manufacturers continue research and development on their respective products.

Low Operating Temperatures and Pressures

Fuel cells operate at 80^{o} C to over $1{,}000^{o}$ C, depending on the type of fuel cell. By comparison, the temperature inside a vehicle's internal combustion engine can reach over $2{,}300^{o}$ C.

Site Flexibility
Fuel cells, with their inherently quiet operation, zero to minimal emissions and reduced permitting requirements, can be located in a variety of areas, both residential and commercial, inside and outside.

Cogeneration Capability
When the waste heat from the fuel cell's electrochemical reaction is captured, it can be utilized for water, space heating and cooling. With cogeneration capabilities, the efficiencies achieved by a fuel cell system approach 90%.

Quick Response to Load Variations
To receive additional energy from a fuel cell, more fuel is introduced into the system. It is much easier to introduce more hydrogen to a fuel cell system than to increase coal burning at a power plant, or increase water flow around a hydro-turbine.

Engineering Simplicity
Fuel cells do not contain any moving parts. The lack of movement allows for a simpler design, high reliability, and quiet operation.

Independence from the Power Grid

> *"The National Power Laboratory estimates that the typical computer location experiences 289 power disturbances a year. U.S. businesses lose $29 billion annually from computer failures due to power outages."*
>
> International Fuel Cells

A residential or commercial fuel cell system allows households and businesses to become independent of the rolling blackouts, power failures, and voltage irregularities associated the utility grid.

TYPES OF FUEL CELLS

There are a number of different types of fuel cells are being developed. The five basic types are the Phosphoric Acid Fuel Cell (PAFC), the Proton-Exchange Membrane Fuel Cell (PEM), the Solid Oxide Fuel Cell (SOFC), the Alkaline Fuel Cell (AFC), and the Molten Carbonate Fuel Cell (MCFC). Fuel cells differ principally in the type of electrolyte used. The characteristics of each type are very different: operating temperature, available heat, tolerance to thermal cycling, power density, tolerance to fuel impurities, etc. These differences make each technology suitable for particular applications. They are also at very different stages of development. Some have not yet fully emerged from the laboratory.[5]

[5] FuelCellWorld.org

Figure 3 below summarizes the types of fuel cells with their concomitant positive and negative attributes as well as likely market applications. **Appendix A** compares the PEM, PAFC, MCFC, and SOFC systems based upon electrolyte, operating temperature, charge carrier, electrolyte state, hardware, catalyst, cogeneration heat, and efficiency.

Figure 3

MAJOR FUEL CELL TECHNOLOGIES			
TYPE	**POSITIVES**	**NEGATIVES**	**LIKELY APPLICATIONS**
Phosphoric Acid	proven, reliable, relatively efficient	large, heavy, high capital cost	offices, industrial applications
Proton-Exchange Membrane ("PEM")	small, light, potentially low capital cost, probably most promising	less proven, relatively low efficiency	homes, automobiles; portable
Solid Oxide	highly efficient, also produces re-usable heat, steam ("cogeneration")	large units, run very hot, for large-scale uses only	offices, industrial applications
Alkaline	well-proven, well-understood, 30 yrs. of experience, high efficiency	aging technology, expensive	military, space; NASA utilizes them for the space shuttle
Molten Carbonate	silent, extremely efficient, also produces re-usable heat, steam	high capital cost, runs very hot, large	industrial applications, ships

Source: *TheStreet.com* research

The following fuel cell descriptions are derived from Jim Seymour's article *Fuel Cells' Technology, Economics Shape Coming Market*, The Street.com - 3/7/01 2:31 PM ET, an interview with Bernadette Geyer of Fuel Cells 2000 - 05/22/01 08:16AM, an interview with Ranji George of the South Coast Air Quality Management District - 05/08/01 08:23PM, and the Fuel Cells 2000 website.

PHOSPHORIC ACID: Used for stationary power for commercial buildings, power for buses or heavy-duty vehicles/trucks. PAFC is the most advanced and has proven to be very durable. More than 200 PAFC fuel cell systems have been installed all over the world - in hospitals, nursing homes, hotels, office buildings, schools, utility power plants, an airport terminal, even a municipal waste dump. It is relatively efficient, but is expensive to produce, roughly $5,000 per kilowatt-hour, installed, and thus suitable only for large commercial installations. The typical PAFC is approximately the size of a car.

ALKALINE: Is the oldest of all the fuel cell technologies. **NASA** used onboard fuel-cell electricity generation in its Gemini and Apollo programs. It can be extremely expensive: The fuel-cell systems used in the space shuttle cost about $600,000 per kilowatt-hour.

Those price tags mean alkaline systems are likely to remain interesting only to the military and other government agencies.

PROTON-EXCHANGE MEMBRANE: Used for small, low-power applications, such as portable computers, remote power, residential power, and automotive power. PEM is the technology that is changing the fastest. It is still in its infancy and many incremental changes are expected. PEM systems are already approaching the size necessary for residential service and are expected to drop to the $5,000-$7,000 range for home-sized units. PEM units are also small and light enough to offer hope for powering cars and trucks, offer quick start up, and run cooler (60-10 C) than other systems. According to the U.S. Department of Energy, "they are the primary candidates for light-duty vehicles, for buildings, and potentially for much smaller applications such as replacements for rechargeable batteries." Several pilot automobiles run on PEM already. The high cost of the platinum catalyst needed by PEM systems was once a problem, but current units require less than a tenth as much platinum as earlier models.


PHOTO COURTESY: IDATECH

MOLTEN CARBONATE: Used for large-scale stationary power applications. Silent but hot, molten-carbonate fuel-cell systems are at the industrial-size applications end of the scale, thanks to both their capital cost and their safety requirements. They also produce, as a result of that high running temperature, steam and heat, which can be recycled in cogeneration to produce high fuel-to-electricity efficiencies. Indeed, in the end, molten-carbonate systems are expensive -- as much as $8,000 per kilowatt-hour -- but are likely to win the high-end market share.

SOLID OXIDE: Used for stationary power applications 5kw and larger, up to megawatt-sized; also can be used for transportation applications. The most technically challenging of the five main fuel-cell technologies, these rely on zirconium oxide as an electrolyte. A sandwich of high-tech ceramics and metal foam, running at 1,500F, a solid-oxide system can achieve efficiency greater than 80%. Like molten-carbonate technology, it throws off a lot of steam and heat, which if recaptured can be used for cogeneration, further increasing efficiency, maybe to as much as 90%. For now, though, solid oxide looks like a future bet.

THE MARKET

"The number one competition is conventional technology, not other fuel cell types or other fuel cell company's . . ."

Paul Lancaster, VP Finance for Ballard Power

Providing electricity to residences and businesses is a $225 billion industry in the United States alone. From electric utilities to oil companies, energy producers have invested billions in an infrastructure to make and distribute energy to consumers. Fuel cells are a disruptive technology to a majority of these companies. In the stationary market, fuel cells have the potential to allow residential and commercial customers to completely detach from the power grid and negate the use of the large, capital-intensive power plants in which utilities have invested. In the mobile market, fuel cells have the potential to make obsolete the gasoline-powered internal combustion engine along with all of the companies that excavate and refine oil. Fuel cells currently cost $2500-3000 kW, which is too expensive for the mainstream commercial market.

"The days of the traditional oil company are numbered, in part because of emerging technologies such as fuel cells for transportation and countries with emerging economies that will exert more control over their natural resources."

Peter I. Bijur, chairman and CEO, Texaco Inc.

As with all new technologies, the fuel cell industry is plagued with the classic market adoption quandary. Fuel cells show great promise but the cost is still too high to achieve adoption in the mainstream marketplace. Barring a monumental breakthrough in production, costs will not decrease until demand rises, and the cycle continues. Marketing has given us a simple equation to follow, Value = Benefits – Costs. Although the benefits of fuel cells are great, the costs to the consumer are still magnitudes greater. **Appendix B** demonstrates the possible economies of scale that could be achieved with increased production.


PHOTO COURTESY: IDATECH

The following market analysis will define the industry in terms of its,

- Value Chain
- Market Drivers
- Leading Companies
- Organizations

and

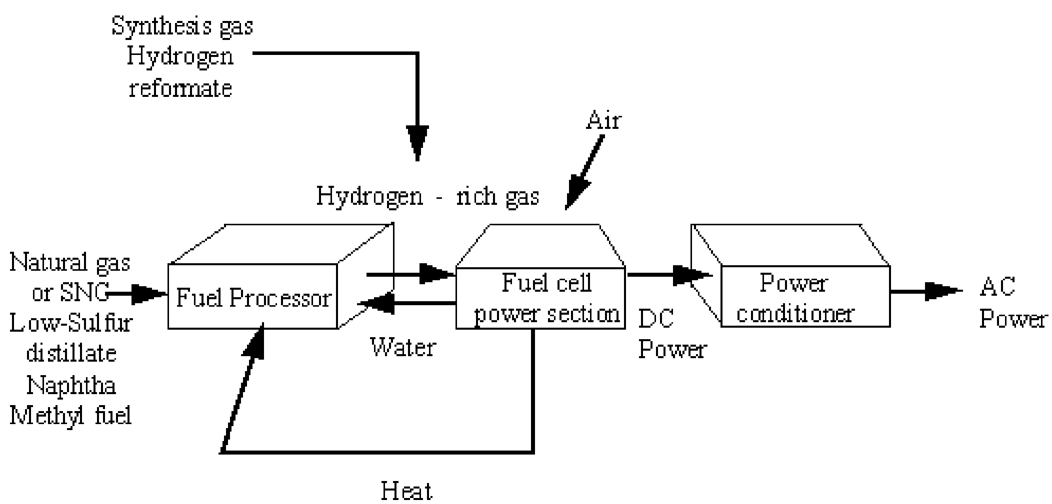
- Academic Resources.

An assessment of Utah's resources in the industry, and recommendations as to how Utah could facilitate commercialization and position itself to capture some of the economic benefits of the industry, are also given. The analysis concludes with recommendations as to how Utah could establish itself as a center for the development of this technology.

THE VALUE CHAIN

The fuel cell technology currently being developed usually consists of three general systems: a fuel reformation unit, a fuel cell power unit, and a power-conditioning unit. These systems are represented in **Figure 4**. Diagram and subsystem explanations are supplied by the Air Force Civil Engineer Support Agency.

Figure 4



FUEL PROCESSING UNIT - This subsystem is responsible for managing the fuel supply to the power section. The fuel processing function can vary from simple control of fuel flow to complex chemical processing. In the latter case, the fuel processor unit converts hydrocarbon fuel to hydrogen. Hydrocarbon fuels include natural gas, light and heavy oils, coal, industrial off-gases, and biomass. The fuel processor is also responsible for filtering the fuel, because small amounts of sulfur compounds may cause a drastic, unacceptable drop in power production.

FUEL CELL POWER UNIT - This section is the heart of the fuel cell power plant. In this subsystem, the chemical reactions responsible for producing electric power take place. The power unit converts the mixture of hydrogen fuel and the oxidant (air) into direct current (dc) power. The power subsystem consists of one or more cell stacks. Each stack contains many individual fuel cells arranged in a series to provide the desired voltage.

POWER CONDITIONING UNIT - This unit converts the output power of the fuel cell to the type of power required by the application, from a simple voltage controller to a complex dc-ac inverter.

The majority if the costs in a fuel cell are associated with the development of the fuel cell power unit or stack, represented by the fuel cell membrane and other stack production. **Appendix C** lists the various types of industries associated with PEM fuel cell production and the relative costs of the various components.

The second most cost-intensive area of the fuel cell is associated with the first subsystem, the Fuel Processing system. The question of how to generate hydrogen for a fuel cell is a problem that has plagued fuel cell developers for years. While hydrogen can be extracted from hydrocarbon fossil fuels, such a system does not provide the advantages of a fuel cell powered by pure hydrogen. Pure hydrogen, however, is a very small molecule that takes energy to isolate and is difficult to contain.

Profit Pool Analysis

A profit pool[6] analysis is much more difficult to do on an emerging market as profits in these industries are nonexistent. However, the principles of a profit pool can be applied to predict areas of the value chain that will be most profitable. The premise of a profit pool is that profits do not automatically follow revenues in a value chain. For example, Ford Co. grosses billions of dollars a year in revenue by selling cars; yet, the high margin-yielding activity is not car production and sales, but rather car financing and service. Similarly, Intel and Microsoft command the highest margins in their respective links on the computer value chain although they do not actually produce and sell computers.

Based upon the types of technologies that are being patented by companies in the industry, the value of the fuel cell will come from its stack components and the hydrogen production and storage for the fuel cell. This leads us to believe that the major producers of these components will initially generate a disproportionate share of the profits in the industry.

[6] Gadiesh, O. & Gilbert, J.L. *How to Map Your Industry's Profit Pools*. HBR May-June 1998

MARKET DRIVERS

"Our long-term vision is of a hydrogen economy."

Robert Purcell Jr., Executive Director of
General Motors National Petrochemical &
Refiners Association's 2000 Annual Meeting

"The fuel cell is the most promising option for the future. We are determined to be the first to bring it to market."

Juergen Hubbert- DaimlerChrysler

"I believe fuel cell vehicles will finally end the hundred-year reign of the internal combustion engine as the dominant source of power for personal transportation. It's going to be a winning situation all the way around - consumers will get an efficient power source, communities will get zero emissions, and automakers will get another major business opportunity - a growth opportunity."

William C. Ford, Jr., Ford Chairman,
International Auto Show, January 2000

"Of all the technologies, the fuel cell car seems to be the most promising, it has a good chance of becoming the next mass market car."

Byron McCormick, co-director of General
Motor's Global Alternative Propulsion Center

"Fuel cell vehicles will probably overtake gasoline-powered cars in the next 20 to 30 years."

Takeo Fukui, managing director, Research
and Development, Honda Motor Co.,
Bloomberg News, June 5, 1999

"Only a few mega trends exist that are of special importance to the future of the automotive industry. Sustainable mobility is one of them, and fuel cells are a key technology for it."

Prof. Klaus-Dieter Voehringer, president of
the Shareholder Committee of XCELLSIS
and president of Research and Technology
of DaimlerChrysler

There are two general types of market segments for which energy is needed: stationary and mobile. There has been much debate among industry experts as to which market segment will adopt and commercialize fuel cells first.

The technology in the industry seem to be caught in the “Chasm” of the product lifecycle as described by Geoffrey Moore in his book, *Inside the Tornado*. Governments have typically taken the role of the early market and subsidized the development of the technology through grants and small-scale purchases of fuel cells despite their high cost and experimental nature.

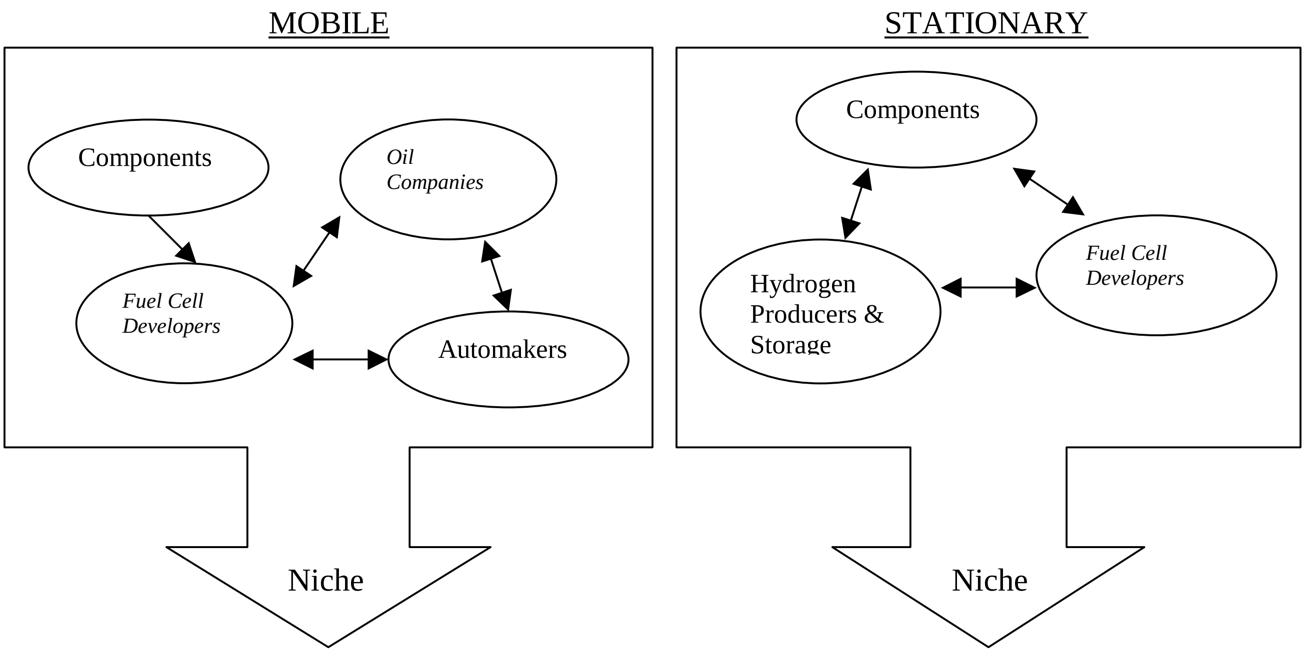
As Moore's writing suggests, the only way to cross the "chasm" is to "win a niche foothold in the mainstream market as quickly as possible."[7] Many different public organizations, companies, and private conglomerates, have coalesced to find this niche and facilitate the commercialization of fuel cells. As will be discussed in detail anon, the market is currently driven by large and powerful auto-makers and oil companies that have teamed up with fuel cell developers to manufacture fuel cell cars that run on petroleum derivatives.

As the quotes at the beginning of this section indicate, the automotive industry is most aggressively pursuing the development of fuel cells. All of the major automakers and all of the major oil companies are involved in the development of fuel cells directly, or indirectly, through organizations whose purpose it is to facilitate the development of fuel cells.

The extent to which the entire value chain of the industry is involved makes a strong case that fuel cells will achieve mass market adoption as a mobile application first. However, power crises in the United Sates, especially in California, have opened up new high-value commercial markets comprised of energy-intensive and energy-critical businesses that are willing to pay a premium for reliable power. Many companies are currently pursuing both segments.

The diagrams on the following page are general in nature but provide a good framework for looking at the two segments.

[7] Moore, Geoffrey A. *Inside The Tornado*. Harper Perennial. 1999. Pg. 22



Consumer Passenger Vehicles

Energy Intensive and Energy Dependent Commercial Facilities

The question of which market niche will be most successful depends on three key factors:

1) Technology Development
2) Access to Niche Market
3) Demand Conditions

Technology Development

> *"People have been trying to sell a hydrogen-based economy for years, ignoring the severe problems with storage and with production. Most of the processes to make hydrogen consume more energy than is eventually available in the hydrogen.*
>
> *Therefore, even though the efficiency of the end conversion unit (like the fuel cell) is high, the overall energy balance is miserable. The weight required to store hydrogen (either as a gas or as a metal hydride) is also enormous, and severely hampers the overall efficiency of transportation when viewed from a broad perspective…. I do not see fuel cells in every car in 20-30 years unless a breakthrough in hydrogen production and storage can be achieved."*

Thomas H. Fletcher - Professor
Director Department of Chemical Engineering
Advanced Combustion Engineering Research Center (ACERC)
Brigham Young University

"Distributing … hydrogen to consumers will require a whole new infrastructure. Without a network of stations able to provide drivers with hydrogen, few consumers are likely to buy hydrogen-powered cars. And, without demand for hydrogen, there is little incentive to build a distribution infrastructure."

Mark Nicholls, *Drive yourself greener*.
January 2001 – Environmental Finance

"The technology has been demonstrated. The main challenge is to bring the costs down and develop an adequate infrastructure to support the fuels."

Ranji George
South Coast Air Quality Management District

"Hydrogen is hard to store and there is no infrastructure set up for is storage or distribution. Also, there is no energy efficient way of extracting hydrogen. In developing an energy system that uses fuel cells, an efficient system for extracting, storing and distributing hydrogen must also be developed. One possible method for extracting hydrogen would be to use solar power to separate out the hydrogen from water. There is an existing infrastructure for storing and distributing fossil fuels, but there is no infrastructure of hydrogen. Before hydrogen and fuel cells can be extensively used as an alternative energy source a hydrogen infrastructure must be developed."

David Lochtefeld – Engineer
Utah Department of Natural Resources

"For fuel cell vehicles, development of a fueling infrastructure is a big hurdle, as fuel cells require hydrogen, but the hydrogen can come from a variety of fuels, including alternative/renewable fuels, as well as traditional fuels. A fuel reformer can extract the hydrogen from the fuel for use in the fuel cell, and the reformer cost/performance/efficiency is something that needs to be worked on to bring down cost, increase efficiency/performance."

Bernadette Geyer, Editor
Fuel Cell Catalyst/Fuel Cell Connection
U.S. Fuel Cell Council

"Hydrogen production, storage, and delivery are major ancillary issues for the commercial development of all fuel cells…In my view, the greatest challenge to a hydrogen economy is the best natural sources of hydrogen (natural gas and hydrocarbon fuels) are more efficiently and effectively used directly as fuels than indirectly as sources of hydrogen that is then used as fuels. It is difficult to develop a process with sufficient efficiency to make the hydrogen economy work."

Larry Baxter - Brigham Young University Professor
Chemical Engineering

The preceding expert citations underscore the importance of the production and storage of hydrogen in the development and commercialization of fuel cells. Hydrogen can be generated through a number of processes as illustrated in **Appendix D**.

While many companies have developed efficient fuel cell systems, the technology to produce and store hydrogen is still very inefficient from an economic standpoint. Hydrogen production and storage is the primary hindrance to the commercialization of fuel cells. The oil companies have ensured their participation in the mobile fuel cell network in order to influence the development of fuel cells with hydrogen from fossil fuel derivatives. An efficient, cost-effective way to produce hydrogen from water or other abundant sources would be extremely disruptive to the oil industry. The reformation of fossil fuels does allow, however, for use of the current infrastructure, which could help bring down costs in the long run.

The major points of the experts are summarized below,

1) Most of the processes to make hydrogen consume more energy than is eventually available in the hydrogen
2) Distributing hydrogen to consumers will require a whole new infrastructure
3) Hydrogen is hard to store
4) The best natural sources of hydrogen (natural gas and hydrocarbon fuels) are more efficiently and effectively used directly as fuels than indirectly as sources of hydrogen

Access to Niche Market

The market strength of the mobile network gives it direct access to the niche it is trying to target. If breakthroughs in technology do occur, this network will be better positioned to respond to the market with its production capability, capital, and existing market channels.

The stationary network has more flexibility with its smaller organization, however it does not have established channels to its target market and does not have the potential production capability. This weakness could be exposed if demand increased suddenly.

Demand Conditions

While the mobile network to contains more capital and market strength, the stationary network has been able to commercialize better in its target niche - most of the fuel cells that are in current operation are used as stationary generators. There are a number of possible explanations for this: 1) Energy intensive and energy dependent businesses are the most demanding consumers for the technology right now and, therefore, are less price sensitive. 2) Refueling of stationary applications is more practical than mobile applications. 3) Consumer Passenger Cars is too broadly defined a niche and, therefore, can't be targeted well.

Out of all those possible explanations, it is the condition of demand in the market that is the most salient. The initial commercial demand for fuel cells has been in stationary applications purchased by the government and from energy intensive/dependent businesses. Many experts believe, however, that the automobiles (see **Appendix E**) running on fuel cells will be the first major market application. Their predictions come partly from technology development of the PEM fuel cell (see **Appendix F**), which is most conducive to mobile applications, but mostly from the demand conditions that they expect in the marketplace.

> *"State board regulations mandate increasing availability for sale of low-emission, ultra-low emission, and zero-emission vehicles, including, by 2003, 10 percent zero-emission vehicles."*
>
> California Health and Safety Code 44001
> Section C - 2

> *"Vehicle manufacturers have entered into a voluntary agreement with the European Union to reduce the CO_2 emissions of the average new car by 25% by 2009."*
>
> Mark Nicholls, Drive yourself greener
> January 2001 – Environmental Finance

California's mandate has had a significant impact on the market for fuel cell vehicles. With over 17 million residents, 10% of the cars in the State add up to a very large market. The most promising market for mobile applications of fuel cells has always resided in California because of the demand that will be created in 2003.

Along with California there are other states that are encouraging the development of fuel cells:

> *"In addition to Connecticut, at least 12 states, (Arkansas, California, Maine, Maryland, Massachusetts, New Jersey, New Mexico, Ohio, Oregon, Rhode Island, Vermont, and Wisconsin), have incentives to promote fuel cells. Among the more common types of measures are financial assistance for fuel cell projects, tax benefits, and inclusion of fuel cells as a type of renewable resource for purposes of laws that require electric suppliers to obtain part of their supply from such sources. The latter type of provision, commonly called a renewable portfolio standard, effectively guarantees a market for eligible technologies. Connecticut offers most of these incentives."*
>
> Kevin E. McCarthy, *FUEL CELL INITIATIVES IN OTHER STATES*. OLR RESEARCH REPORT – State of Connecticut, June 7, 2000

If a country were to be picked as the "fuel cell nation" it would not be the United States. Canada is home to the leading fuel cell developer Ballard Power Inc., of which a more extensive description will be given in the next section.

> *"The Canadian federal government has recently committed $17.6 million for a national fuel-cell research center….By 2020, industry leaders believe the global fuel-cell industry will be valued at anywhere from $60 billion to $590 billion. The commitment by the federal government is intended to place Canada at the forefront of the fuel cell industry."*
>
> Anna Abe, *Fuel Cell Market Analysis.*
> Massachusetts Small Business Development
> Center Network, July 2000

Some have predicted that the stationary market will be dominated by electric utilities that buy up large amounts of fuel cells or acquire fuel cell companies as soon as the market matures. While reasonable, the argument is unconvincing. Utilities have the incentive to keep people on the grid, not provide means to take them off. While oil companies and automakers have invested hundreds of millions of dollars in research, utilities have been relatively unmoved. For a litany of reasons that will not be enumerated here, utilities are not structured organizationally or strategically to develop fuel cells.

> *Scratch the surface of most utilities, regardless of their public posture embracing change, deregulation and customer choice, and you'll find the thriving spirit of a regulated monopoly longing to continue the days of adequate, relatively low risk return on infrastructure investment and wistfully hoping for just such a future. The problem, however, is not simply the inability of the management culture to cope with the risk burden and entrepreneurial actions required of unregulated distributed energy markets, but the inertia and cost inherent in utilities…. Utility labor, work practices, cost accounting and culture will ultimately kill the economic potential of distributed energy within utilities. This is a business for entrepreneurs who are not risk averse.*
>
> Gerry Runte, *Five Fuel Cell Myths*
> DIRECTOR, EASTERN REGIONAL OFFICE,
> M-C POWER CORPORATION

THE INDUSTRY

The fuel cell industry is composed of companies (see **Appendix G**) currently developing fuel cells, companies developing ways of producing and storing hydrogen, and coalitions facilitating the commercialization of fuel cells. Different companies are working on each of the fuel cell technologies and developing them for specific market niches. Coalitions of fuel cell developers, oil companies, automakers, government agencies, and academic institutions have helped to promote the development of fuel cells, especially for mobile market uses. Company information is derived from Hovers Online www.hoovers.com and Wright Investors' Service www.wisi.com unless otherwise indicated.

COMPANIES

> *"The fuel cell market year 2000 was one of factory building and initial public offerings (IPOs) in the fuel cell industry, while 2001 should see steadily increasing commercial production. Many of the major players, including Ballard Power, FuelCell Energy, and Plug Power, began building and expanding factories scheduled to begin production in 2001."*
>
> January 2001 Fuel Cell Tech News

MAJOR FUEL CELL PLAYERS

COMPANY	TECHNOLOGIES	"APPARENT MARKET FOCUS"	"STATUS / NOTES"
Ballard Power (BLDP:Nasdaq)	PEM, direct methanol	automotive, residential	best-known player, DaimlerChrysler connection
Plug Power (PLUG:Nasdaq)	PEM	small commercial, residential	promise deliveries in 2001; GE connection?
Intl. Fuel Cells division of United Technologies (UTX:NYSE)	alkaline, phosphoric acid, PEM	commercial, residential, automotive	most established player; watch for spinout
FuelCell Energy (FCEL:Nasdaq)	molten carbonate	commercial, industrial	have a few early customers, very promising in niches

Source: *TheStreet.com* research

In addition to the "major players," there are a number of other companies that are considered primary developers in the specific fuel cell technology areas.

Proton Exchange Membrane (PEM) Fuel Cells: H Power, Avista Labs, Nuvera, Energy Partners, DCH Technology, Motorola, Anuvu, Directed Technologies Inc., ElectroChem, Honeywell, Manhattan Scientifics, Proton Energy Systems.

Phosphoric Acid Fuel Cells: ONSI, E-TEK, Fuji Electric Company, Haldor Topsoe, Mitsubishi, and Toshiba.

Solid Oxide Fuel Cells: SiemensWestinghouse, Ceramic Fuel Cells Limited, Fuel Cell Technologies, Global Thermoelectric, Honeywell, McDermott Technology, NexTech Materials, and SOFCo.

Molten Carbonate Fuel Cells: Bechtel Corporation, Fuji Electric, Hitachi Works, Mihama, and Toshiba.

Source: Bernadette Geyer, Editor Fuel Cell Catalyst/Fuel Cell Connection U.S. Fuel Cell Council

INDUSTRY SUMMARY

The summary graphs in **Appendix H** and **Appendix I** paint a picture of the industry and the main companies within it. Ballard is recognized as the industry leader as evidenced by its huge market cap. International Fuel Cells, the company that provides electricity for the space shuttle, is a division of United Technologies and has the most employees of all the major companies. While Ballard spends the most on R&D, Fuel Cell Energy spends the least and has the best sales/employee ratio. Some of the companies were slightly profitable a few years ago, however, the losses have been mounting in recent years.

Ballard Power Systems Inc.

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Top Officers

Chairman and CEO: Firoz A. Rasul, age 48
President and COO: Layle K. (Kip) Smith, age 44
VP and Chief Technical Officer; President and CEO, Ballard Advanced Materials Corporation: Alfred E. Steck, age 49
VP, Finance: Paul Lancaster, age 40
VP, Operations: Eamonn Percy, age 38
VP; President, Ballard Automotive: Neil C. Otto, age 50
VP; President, Ballard Generation Systems: James Kirsch, age 42
VP, Strategic Development and Corporate Secretary: Noordin S. K. Nanji, age 40
Director, Human Resources: Michael Roberts
Auditors: PricewaterhouseCoopers LLP
Total Employees: 675
1-Yr. Employee Growth: 35.0%

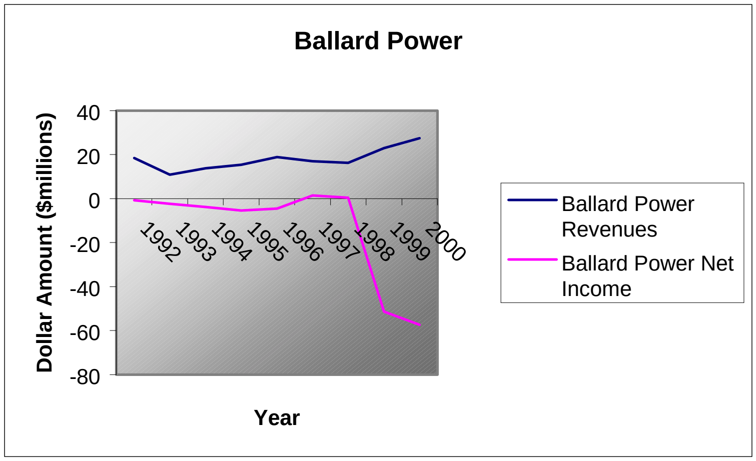
DaimlerChrysler and Ford own 18 percent and 14 percent of Ballard, respectively.

NASDAQ NM: BLDP

SALES ANALYSIS

Sales were up sharply during the first quarter of 2001 versus the previous year's first quarter. During the first quarter of 2001, sales at Ballard Power totaled C$20.02 million. This is an increase of 397.8% from the C$4.02 million in sales at the company during the first quarter of 2000.

Ballard Power reported sales of C$41.09 million (US$26.75 million) for the year ending December of 2000. With 675 employees this adds up to $60,874 per employee. This represents an increase of 23.9% versus 1999, when the company's sales were C$33.15 million. This was the third consecutive year of growth at Ballard Power. Sales of Fuel Cell Systems saw an increase that was more than double the company's growth rate: sales were up 60.7% in 2000, from C$11.41 million to C$18.34 million. Not all segments of Ballard Power experienced an increase in sales in 2000: sales of Fuel Cells fell 23.4% to C$22.74 million.



Fuel cells accounted for 55% of 2000 revenues and fuel cell systems, 45%. Sales of Fuel Cells accounted for only 55% of sales in 2000, versus 100% in 1996. Just over half of the company's 2000 sales were in Germany: in 2000, this region's sales were C$20.91 million, which is equivalent to 50.9% of total sales. In 2000, sales in Germany were up at a rate that was much higher than the company as a whole: in this region, sales increased 178.0% to C$20.91 million. Ballard Power also experienced significant increases in sales in Canada (up 60.0 percent to C$3.04 million) . Although the company's overall sales increased, sales were not up in all regions of the world: sales in the United States were down 47.3 percent (to C$7.36 million) and sales in Other countries fell 50.5 percent (to C$262,000.00) .


The Ballard® Mark 900 Series Fuel Cell Power Module

INVENTORY ANALYSIS

As of December 2000, the value of the company's inventory totaled C$17.64 million. Since the cost of goods sold was C$55.07 million for the year, the company had 117 days of inventory on hand (another way to look at this is to say that the company turned over its inventory 3.1 times per year). In terms of inventory turnover, this is a significant improvement over December 1999, when the company's inventory was C$8.65 million, equivalent to 136 days in inventory.

R&D

Research and Development Expenses at Ballard Power in 2000 were C$86.50 million, which is equivalent to 210.5 percent of sales. In 2000 R&D expenditures increased both as a percentage of sales and in actual amounts: In 1999, Ballard Power spent C$62.03 million on R&D, which was 187.1 percent of sales. During each of the previous five years, the company has increased the amount of money it has spent on Research and Development (in 1995, Ballard Power spent C$12.85 million versus C$86.50 million in 2000).

FINANCIAL POSITION

As of December 2000, the company's long-term debt was C$191,000.00 and total liabilities (i.e., all monies owed) were C$62.26 million. The long-term debt to equity ratio of the company is very low, at only 0.00.

The company has a large cash balance: in 2000, the company had only C$41.09 million in sales, but its cash and short term investments as of December 2000 were C$769.67 million, or 18.7 times the annual sales. Ballard Power does not appear to be very efficient in collecting payments: As of December 2000, the accounts receivable for the company were C$23.05 million, which is equivalent to 205 days of sales. This is an improvement over the end of 1999, when Ballard Power had 296 days of sales in accounts receivable.

Plug Power Inc.

968 Albany-Shaker Rd.
Latham, NY 12110
Phone: 518-782-7700
Fax: 518-782-9060
http://www.plugpower.com

Top Officers

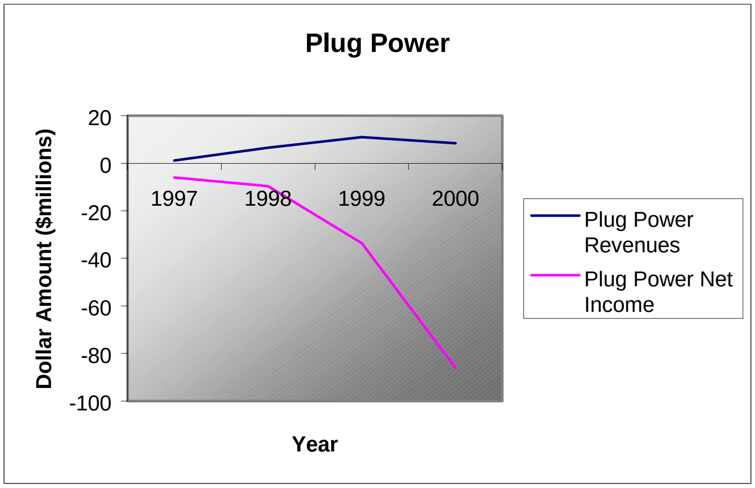
Chairman: George C. McNamee, age 54
President, CEO, and Director: Roger B. Saillant, age 57, $85,875 pay
CFO and Treasurer: William H. Largent
SVP, Operations: Gregory A. Silvestri, age 40, $265,608 pay
SVP, Corporate Development: Louis R. Tomson, age 60, $138,077 pay
VP and Chief Marketing Officer: Mark Sperry, age 40, $164,615 pay (partial-year salary)
VP and Chief Scientist: William D. Ernst, age 61
VP, Manufacturing: Paul Burton, age 40
VP, Engineering: Robert Sinuc, age 56
VP, Research and System Architecture: John Elter, age 59
Chief Technology Officer: Glenn A. Eisman, age 50
General Counsel and Secretary: Ana-Maria Galeano, age 33
Director, Human Resources: Tina S. Leonard
Auditors: PricewaterhouseCoopers LLP
Total Employees: 537
1-Yr. Employee Growth: 70.5 percent

Plug Power was founded as a joint venture between DTE Energy and Mechanical Technology. DTE Energy directors Anthony Earley Jr. and Larry Garberding together own 32 percent of the company; Plug Power chairman George McNamee also owns 32 percent.

NASDAQ NM: PLUG

SALES ANALYSIS

Sales levels dropped significantly in the first quarter of 2001 versus the previous year's first quarter. During the first quarter of 2001, sales at Plug Power Incorporated totaled $1.03 million. This is a drop of 65.0% from the $2.93 million in sales at the company during the first quarter in 2000.



Plug Power Incorporated reported sales of $8.38 million for the year ending December of 2000. This represents a sharp decrease of 23.8% versus 1999, when the company's sales were $11.00 million. Plug Power Incorporated currently has 537 employees. With sales of $8.38 million , this equates to sales of US$15,601 per employee.

INVENTORY ANALYSIS

As of December 2000, the value of the company's inventory totaled $2.17 million. Since the cost of goods sold was $7.22 million for the year, the company had 110 days of inventory on hand (another way to look at this is to say that the company turned over its inventory 3.3 times per year). This is an increase in days in inventory from December 1999, when the company had $304,711.00 , which was only 8 days of sales in inventory.

R&D

Research and Development Expenses at Plug Power Incorporated in 2000 were $65.91 million, which is equivalent to 786.6 percent of sales. In 2000 R&D expenditures increased both as a percentage of sales and in actual amounts: In 1999, Plug Power Incorporated spent $20.51 million on R&D, which was 186.4 percent of sales.

FINANCIAL POSITION

As of December 2000, the company's long-term debt was $5.34 million and total liabilities (i.e., all monies owed) were $16.70 million. The long-term debt to equity ratio of the company is very low, at only 0.04.

The company has a large cash balance: in 2000, the company had only \$8.38 million in sales, but its cash and short term investments as of December 2000 were \$87.02 million, or 10.4 times the annual sales. As of December 2000, the accounts receivable for the company were \$1.42 million, which is equivalent to 62 days of sales. This is an improvement over the end of 1999, when Plug Power Incorporated had 173 days of sales in accounts receivable.

United Technologies Corporation

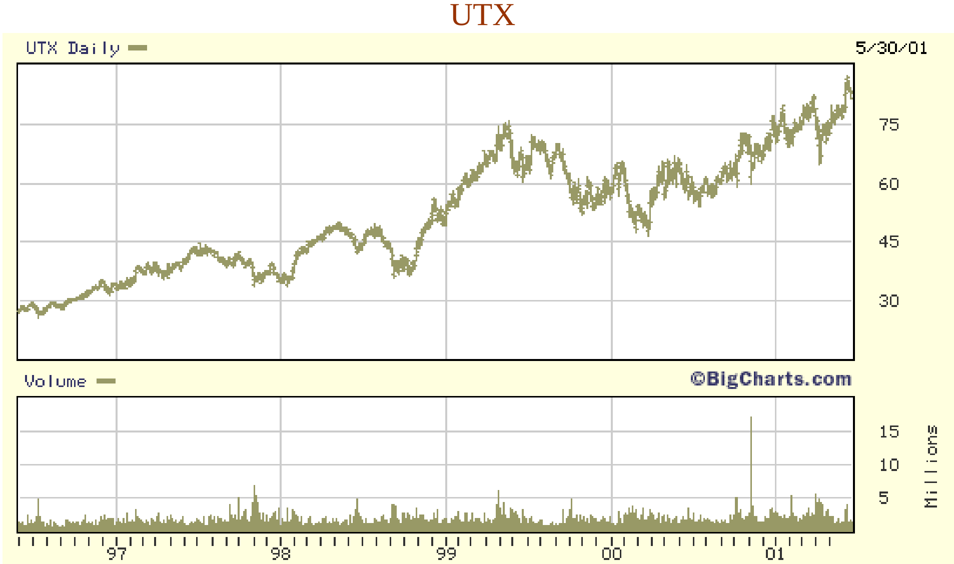
One Financial Plaza
Hartford, CT 06103
Phone: 860-728-7000
Fax: 860-728-7979
http://www.utc.com

Officers & Employees

Chairman and CEO: George David, age 57, $3,600,000 pay
President, COO, and Director: Karl J. Krapek, age 52, $2,079,167 pay
EVP; President and CEO, Otis Elevator: Stephen F. Page, age 61, $1,327,500 pay
EVP and COO, Otis Elevator: Ari Bousbib, age 39
SVP, CFO, and Treasurer: David J. FitzPatrick, age 46
SVP, General Counsel, and Secretary: William H. Trachsel, age 57
SVP, Human Resources and Organization: William L. Bucknall Jr., age 58
SVP, International Affairs and Government Relations; Chair, United Technologies International: Ruth R. Harkin, age 56
SVP, Science and Technology: John F. Cassidy, age 57

President, Hamilton Sundstrand: Ronald F. McKenna, age 60
President, Pratt & Whitney: Louis Chênevert, age 43
President, Sikorsky Aircraft Corporation: Dean C. Borgman, age 59
President, Carrier Corporation: Jonathan W. Ayers, age 44
President, International Fuel Cells: William T. Miller
EVP and COO, Pratt & Whitney: Robert Leduc
EVP, Toshiba-Carrier: William R. brown
SVP, Engineering, Pratt & Whitney: D. Edward Crow
Auditors: PricewaterhouseCoopers LLP
2000 Employees: 153,800
1-Year Employee Growth: 3.7%

UTX

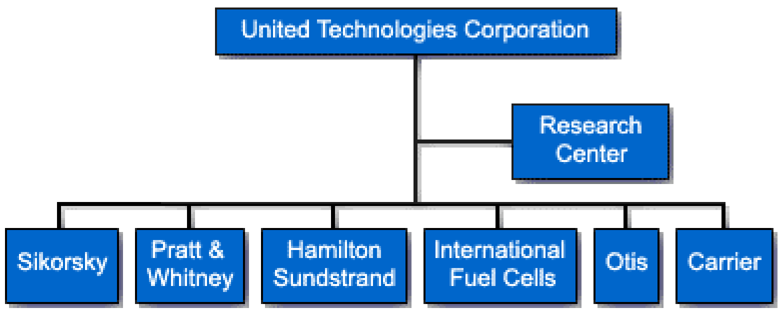


Subsidiary INTERNATIONAL FUEL CELLS

IFC has supplied electric power for the U.S. manned space program since 1966 in the Apollo and Space Shuttle orbiter vehicles. The only commercial fuel cell, the 200 kW PC25™ power plant has been providing premium quality electric power and useful heat to buildings around the world since it was introduced by IFC in 1992.

Officers & Employees

President, International Fuel Cells: William T. Miller
Engineers, Researchers, Managers, Production Workers: 750



SOURCE: www.internationalfuelcells.com

Stock: N/A

HISTORICAL FINANCIALS AND EMPLOYEES (Estimated*) Income Statement				
YEAR	**REVENUE ($ mil.)**	**NET INCOME ($ mil.)**	**NET PROFIT MARGIN**	**EMPLOYEES (as of 2001)**
1991-2001	424.0	40	9.4%	750

** Revenue based upon sales of over 200 PC25 fuel cell power plants between 1991 and 2001, and estimate of $200 million associated with space shuttle fuel cell revenue. Installed cost of $1,120,000 for one PC25 (Sales amounts and costs derived from information on International Fuel Cell website). NI and PM are estimates based upon industry analysis and revenue streams from government contracts or licenses, minus estimation of R&D attributed to the subsidiary.*

FuelCell Energy, Inc.

Three Great Pasture Rd.
Danbury, CT 06813
Phone: 203-825-6000
Fax: 203-825-6100
http://www.fuelcellenergy.com

Top Officers

Chairman: Bernard S. Baker, age 64
President and CEO: Jerry D. Leitman, age 57, $449,210 pay
EVP and Chief Technology Officer: Hansraj C. Maru, age 56, $234,167 pay
EVP and COO: Christopher R. Bentley, age 58, $293,862 pay
SVP, CFO, Secretary, and Treasurer: Daniel J. Samela, age 52, $247,613 pay
SVP Marketing and Sales: Herbert T. Nock, age 51
Director of Human Resources: Rena Cherry
Auditors: KPMG LLP
Total Employees: 152
1-Yr. Employee Growth: 33.3%

Loeb Partners owns 10 percent of FuelCell; MTU, 11 percent.

FCEL

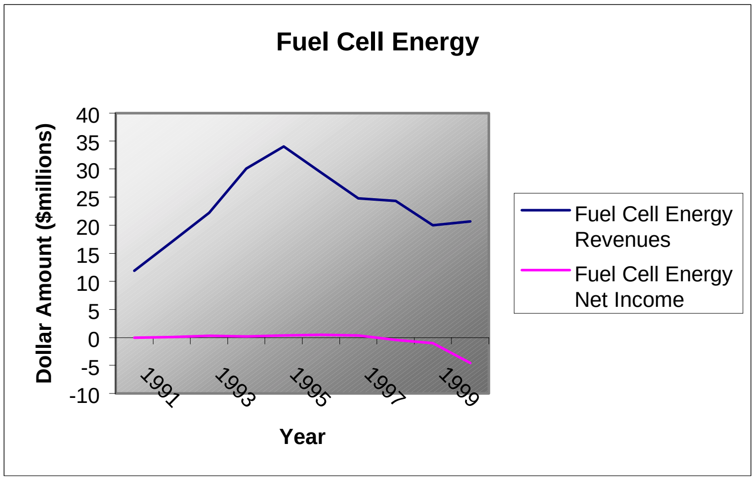
BigCharts.com ranked Fuel Cell Energy as the best performing stock in the fuel cell industry over the past two years

Symbol	Company Name	Percent Change
FCEL	Fuelcell Energy Inc	1,623.68%

SALES ANALYSIS

During the first calendar quarter of 2001, sales at Fuelcell Energy totaled $5.33 million. This is an increase of 48.1 percent from the $3.60 million in sales at the company during the first quarter of 2000.

Fuelcell Energy reported sales of $20.72 million for the fiscal year ending October of 2000. This represents an increase of 3.8 percent versus 1999, when the company's sales were $19.97 million. Despite this increase, sales are still well below the level achieved in 1998, when Fuelcell Energy reported sales of $25.00 million. Fuelcell Energy currently has 152 employees. With sales of $20.72 million , this equates to sales of US$136,283 per employee.



INVENTORY ANALYSIS

As of October 2000, the value of the company's inventory totaled $305,000.00 . Since the cost of goods sold was $15.73 million for the year, the company had seven days of inventory on hand (another way to look at this is to say that the company turned over its inventory 51.6 times per year).

R&D

Research and Development Expenses at Fuelcell Energy in 2000 were $1.92 million, which is equivalent to 9.3 percent of sales. In 2000 R&D expenditures increased both as a percentage of sales and in actual amounts: In 1999, Fuelcell Energy spent $1.81 million on R&D, which was 9.1 percent of sales.

FINANCIAL POSITION

This company has a large cash balance: in 2000, the company had only $20.72 million in sales, but its cash and short term investments as of October 2000 were $74.75 million, or 3.6 times the annual sales. As of October 2000, the accounts receivable for the company were $3.46 million, which is equivalent to 61 days of sales.

Siemens Corporation

153 E. 53rd. St.
New York, NY 10022-4611
Phone: 212-258-4000
Fax: 212-767-0580
Toll Free: 800-743-6367
http://www.usa.siemens.com

Top Officers

Chairman; Member, Managing Board, Human Resources, Siemens AG: Peter Pribilla, age 59
President and CEO: Gerhard Schulmeyer
COO: Klaus Kleinfeld, age 43
EVP and CFO: Gerald Wright
SVP, Direct/Intermediary Group: Bob Anderson
SVP, Vendor Receivables: Richard Kershaw
President and CEO, Siemens Automotive: John Sanderson
President and CEO, Siemens Building Technologies: Thomas J. Malott
President and CEO, Siemens Business Services: Walter Gerdes
President and CEO, Siemens Corporate Research: Thomas Grandke
President and CEO, Siemens Financial Services: Bill Zadrozny
President and CEO, Siemens Information and Communications Networks: Fred Fromm
President and CEO, Siemens Medical Systems: Thomas N. McCausland
President and CEO, Siemens Power Transmission and Distribution: Jan van Dokkum
President, OSRAM Sylvania: Dean T. Langford
President, Siemens Shared Services: Gregory Finley
VP and Managing Director, Siemens Financial Services: Michael Coiley
VP, Energy Management Information Systems: Greg Johnson
Auditors: KPMG Peat Marwick LLP
Total Employees: 80,000
1-Yr. Employee Growth: 25.2%

Siemens Power Generation

Group Managing Board: Klaus Voges (Chairman), Andreas Kley, Norbert König, Randy Zwirn
Net sales: 8,270 million Euro
New orders: 9,409 million Euro
Employees: nearly 27,000
Stationary Fuel Cells
located in USA (SWPC)

- Thomas Voigt
- Mark Bennie

Siemens Power Generation has been developing tubular Solid Oxide Fuel Cells (SOFC) aimed at commercializing them for distributed generation segments of the stationary power market. Orders for commercial SOFC power plants are expected to be taken as early as 2002, with first deliveries being made in 2004. Source: Siemens Corporate Website – www.pg.seimens.com

H Power Corp.

1373 Broad St.
Clifton, NJ 07013
Phone: 973-450-4400
Fax: 973-450-9850
http://www.hpower.com

Top Officers

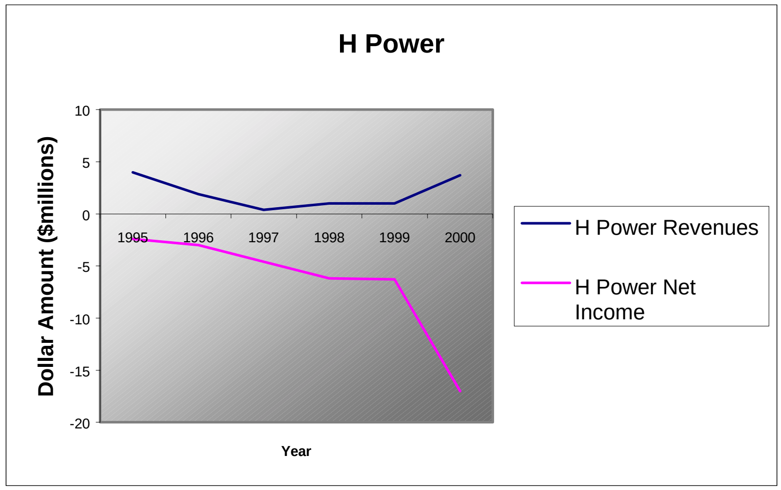
CEO: H. Frank Gibbard, age 59, $195,776 pay
CFO: William L. Zang, age 47, $120,000 pay
Chief Technology Officer: Arthur Kaufman, age 63, $134,722 pay
VP, Administration and Assistant Secretary: Thomas H. Michael, age 44
VP, Research and Development: Alan Attia, age 57
General Manager, H Power Enterprises, Canada, Inc.: Jean-Guy Chouinard, age 49
Director, Human Resources: Michelle Schardt
Auditors: PricewaterhouseCoopers LLP
Total Employees: 141
1-Yr. Employee Growth: 11.9%

Founders Norman Rothstein and Frederick Entman and their families own about 19 per and 17 percent of the company, respectively.

HPOW

SALES ANALYSIS

During the first calendar quarter of 2001, sales at H Power Corp. totaled $831,148.00. Sales increased substantially in 2000: During the year ended May of 2000, sales at H Power Corp. were $3.68 million. This is an increase of 261.5% versus 1999, when the company's sales were $1.02 million. This was the fourth straight year of sales growth at H Power Corp. The company derives almost all of its revenues in its home market of the United States: in 2000, this region's sales were $3.33 million, which is equivalent to 90.6% of total sales. The company currently employs 141. With sales of $3.68 million , this equates to sales of US$26,101 per employee.



INVENTORY ANALYSIS

As of May 2000, the value of the company's inventory totaled $1.30 million. Since the cost of goods sold was $2.80 million for the year, the company had 169 days of inventory on hand (another way to look at this is to say that the company turned over its inventory 2.2 times per year). In terms of inventory turnover, this is a significant improvement over May 1999, when the company's inventory was $341,119.00 , equivalent to 208 days in inventory.

R&D

Research and Development Expenses at H Power Corp. in 2000 were $5.34 million, which is equivalent to 145.1 percent of sales. In 1999, H Power Corp. spent $3.05 million on R&D, which was 299.7 percent of sales. During each of the previous 3 years, the company has increased the amount of money it has spent on Research and Development (in 1997, H Power Corp. spent $2.11 million versus $5.34 million in 2000).

FINANCIAL POSITION

As of May 2000, the company's long-term debt was $66,765.00 and total liabilities (i.e., all monies owed) were $5.26 million. The long-term debt to equity ratio of the company is very low, at only 0.00. This company has a large cash balance: in 2000, the company had only $3.68 million in sales, but its cash and short term investments as of May 2000 were $113.30 million, or 30.8 times the annual sales.

H Power Corp. does not appear to be very efficient in collecting payments: As of May 2000, the accounts receivable for the company were $2.02 million, which is equivalent to 201 days of sales. This is an improvement over the end of 1999, when H Power Corp. had 346 days of sales in accounts receivable.

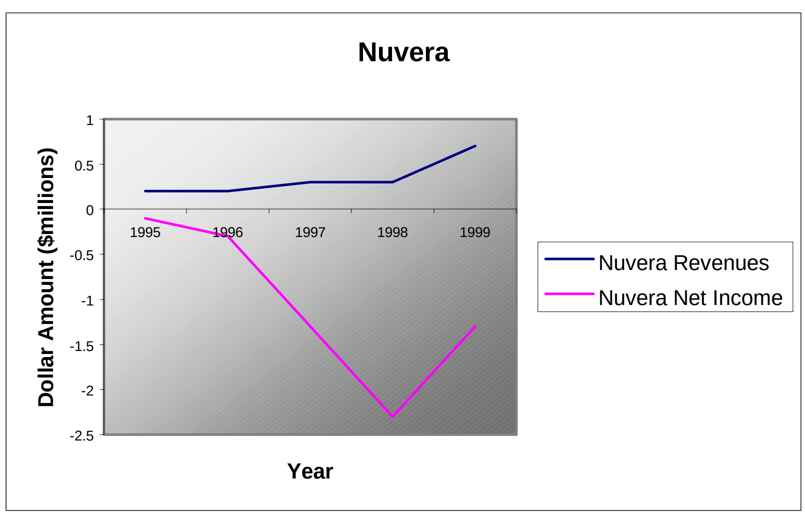
Nuvera Fuel Cells, Inc. (private)

15 Acorn Park
Cambridge, MA 02140
Phone: 617-498-6000
Fax: 617-498-6655
http://www.nuvera.com

Top Officers

President: Mark A. Brodsky, age 44
SVP and COO: Jeffrey Bentley, age 46
SVP and COO, Nuvera Europe: Michele Tettamanti, age 40
VP, Engineering: William L. Mitchell, age 34
Director, Research and Development: James C. Cross III, age 35
Technical Manager, Nuvera Europe: Antonio Maggiore, age 36
Principal Engineer: Lawrence G. Clawson, age 62
Senior Manager: Srinivasa K. Prabhu, age 33
Senior Manager: Prashant S. Chintawar, age 31
Sales Manager, Nuvera Europe: Alessandro Delfrate, age 38
Production Manager, Nuvera Europe: Giampaola Sibila, age 36
Treasurer: Lou Persico, age 45
Secretary and Acting General Cousel: Anne O'Brien Troutman, age 44
Controller: Danny Wong, age 36
Controller, Nuvera Europe: Silvio Monti, age 35
Director, Human Resources: Aziz Chowdhury
Program Manager: Stephen G. Block, age 43
Manager, Experimental Activities and Laboratories, Nuvera Europe: Katia Franchi, age 30
Total Employees: 161

The company is developing clean-burning fuel processors and fuel cell systems for cars, buses, telecommunications backup systems, and consumers' homes. Nuvera's fuel processors extract hydrogen from common fuels such as gasoline, methanol, kerosene, and propane. The extracted hydrogen can then be used in the company's proton exchange membrane (PEM) fuel cells to produce electricity. Nuvera was formed early in 2000 by the merger of Italy's De Nora Fuel Cells and Epyx Corp. (a division of Arthur D. Little, Inc.). De Nora owns 46% of Nuvera; Arthur D. Little, Inc., owns 37%; and energy giant Amerada Hess owns 16%.



HYDROGEN PRODUCERS

Proton Energy Systems, Inc.

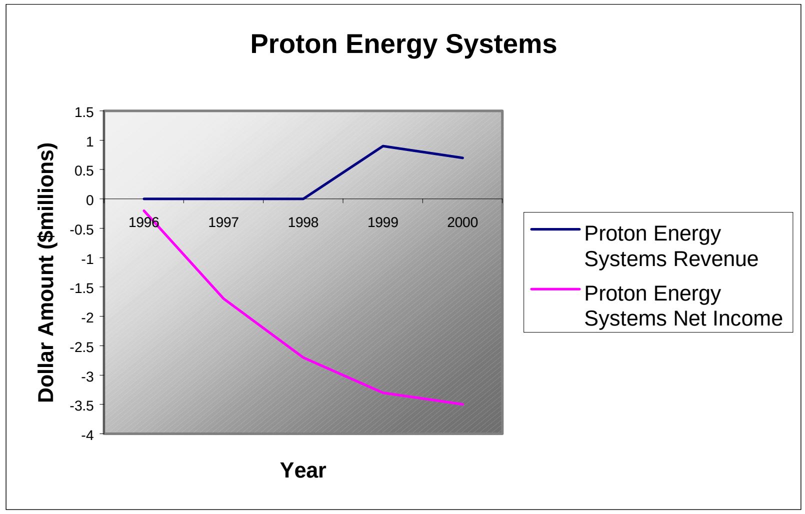
50 Inwood Rd.
Rocky Hill, CT 06067
Phone: 860-571-6533
Fax: 860-571-6505
http://www.protonenergy.com

Top Officers

Chairman: Robert W. Shaw Jr., age 58
President, CEO, and Director: Walter W. Schroeder, age 52, $414,501 pay
VP, Engineering and Technology, and Director: Trent M. Molter, age 38, $198,202 pay
VP, Operations: Robert J. Friedland, age 35, $169,573 pay
VP, Product Engineering: Lawrence W. Moulthrop Jr., age 44, $147,411 pay
VP, Business Development: William F. Smith, age 49
VP, Sales and Marketing: David E. Wolff, age 43
VP, Finance: John A. Glidden, age 37
Auditors: PricewaterhouseCoopers LLP
Total Employees: 50
1-Yr. Employee Growth: 66.7%

NASDAQ NM: PRTN

The company makes proton exchange membrane (PEM) electrochemical devices, such as hydrogen generators and regenerative fuel cells. Proton Energy's HOGEN hydrogen generators produce high-purity hydrogen from electricity and water for use with fuel cells and for a wide variety of manufacturing and laboratory applications. The company's UNIGEN regenerative fuel cells convert electricity to hydrogen so it can be stored and converted back to electricity as needed. The UNIGEN fuel cell can be used for backup power needed for computer and communications networks. Through Arete Corporation, the Micro-Generation Technology Fund owns 16% of Proton Energy.



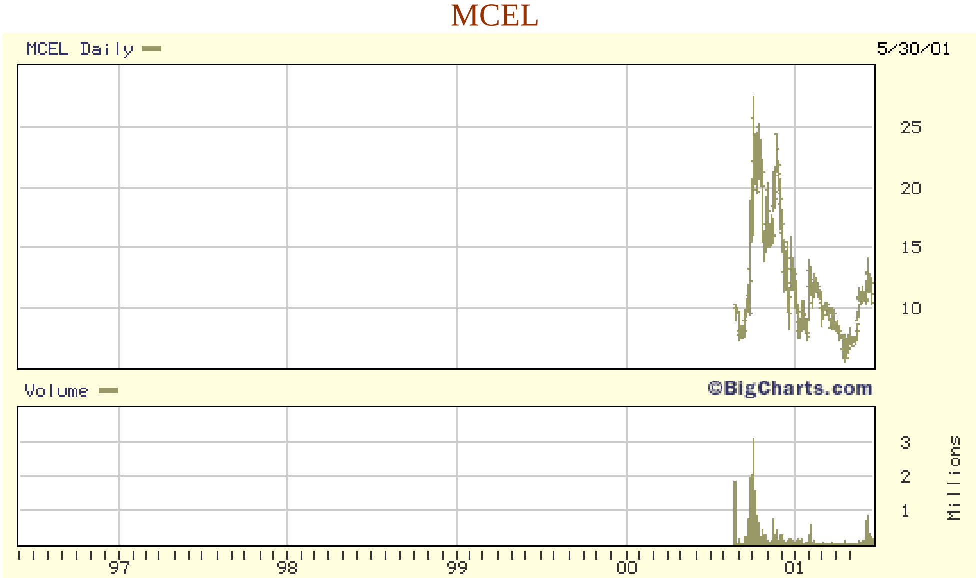
Millennium Cell LLC

1 Industry Way West
Eatontown, NJ 07724
Phone: 732-542-4000
Fax: 732-542-4010
http://www.millenniumcell.com

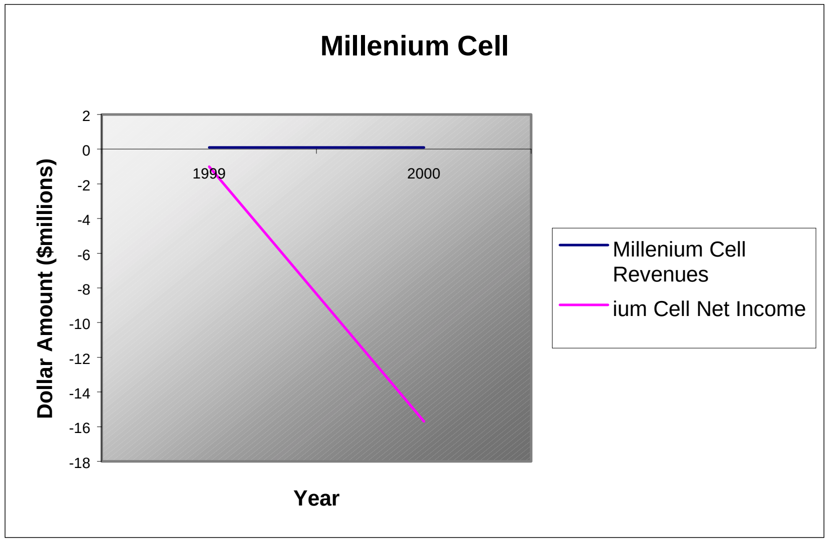
Top Officers

Chairman: G. Chris Andersen, age 62
President, CEO, and Director: Stephen S. Tang, age 40, $276,667 pay
EVP, Chief Science Advisor and Director: Steven Amendola, age 46, $377,083 pay
VP, Finanace and Administration; CFO, and Secretary: Norman R. Harpster Jr., age 49
VP, Business Development and Portable Power: Adam P. Briggs, age 39
VP, Business Development and Supply Chain: Curtis C. Cornell, age 54
VP, Business Development and Transportation : Rex E. Luzader, age 52
VP, Marketing and Communications: Katherine M. McHale, age 45
VP, Product Development: Terry M. Copeland, age 49
Human Resources Director: George Zalepa
Auditors: Ernst & Young LLP
Total Employees: 38
1-Yr. Employee Growth: 111.1%

MCEL

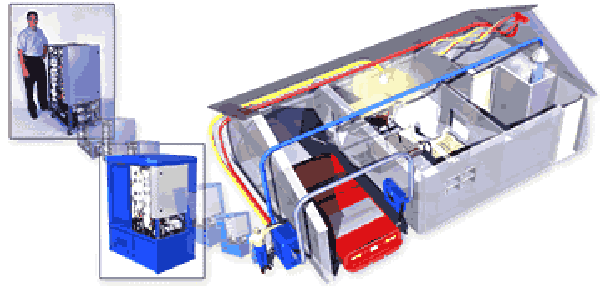


The development-stage company's patented Hydrogen on Demand system uses a boron chemistry process to generate pure hydrogen from safe raw materials. In this process, the energy potential of hydrogen is stored in sodium borohydride. Then, in the presence of a catalyst, hydrogen is produced which can be used to generate electricity in a fuel cell or battery. The system can also be used in internal combustion engines that have been modified to burn hydrogen. Millennium Cell has built a hydrogen system for an SUV prototype and is working with DaimlerChrysler to develop the technology for future vehicles. GP Strategies owns 22% of the company.



Hydrogen Burner Technology, Inc.

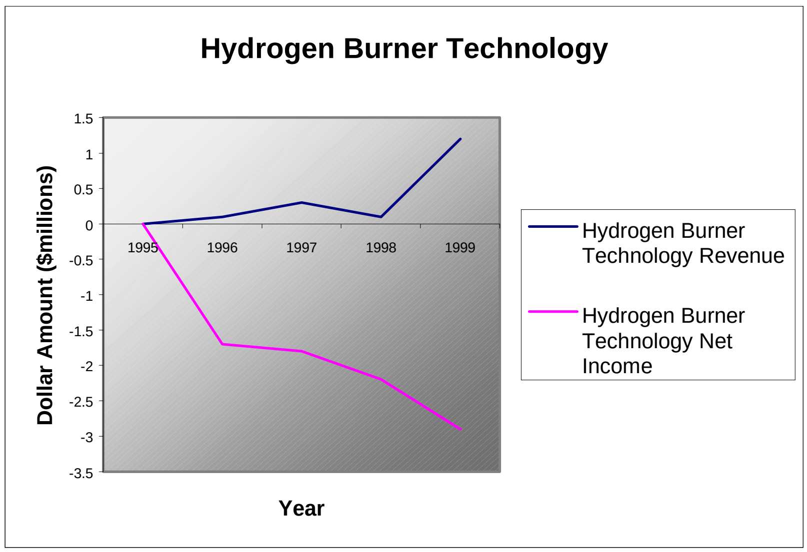
19300 Susana Rd.
Rancho Dominguez, CA 90221
Phone: 310-900-0400
Fax: 310-900-0410
http://www.hydrogenburner.com



Key People

President and CEO: David M. Moard
CFO: Michael Burke
***Human Resources Manager**: Cindy McKinley*

The company makes hydrogen fuel processors for fuel cells used in transportation, residential, and small commercial applications, as well as industrial hydrogen generators for stationary manufacturing applications. HBT, which believes its Under-Oxidized Burner produces energy more efficiently than current methods, introduced its first industrial hydrogen generation system in 1997 and is close to introducing fuel processors for fuel cells. The company is also developing hydrogen generation systems for hydrogen refueling stations to be used with alternative fuel municipal bus systems and fleet vehicles.



ORGANIZATIONS

Below is a list of various academic institutions, industry consortiums, and research centers that are working to develop and/or commercialize fuel cells. The most prominent among these is the California Fuel Cell Partnership (see **Appendix J**) which itself is a consortium of fuel cell technology developers, government, research institutes, demonstration partners, and fuel infrastructure partners. Ballard Power is the founding member of the California Fuel Cell Partnership.

One other notable in the California Fuel Cell Partnership is SunLine Transit Agency, a public organization that serves the Coachella Valley in California. In a bold move SunLine Transit converted its entire fleet of buses to Compressed Natural Gas in 1994 and instantly became a leading organization in the development of clean fuel technology. Alternative energy companies were attracted to such a risk-taker and have partnered with it ever since. SunLine transit now owns the greatest concentration per capita in the United States.

American Hydrogen Association
California Fuel Cell Partnership
California Hydrogen Business Council (CH2BC)
Ernest B. Yeager Center for Electrochemical Sciences Case Western Reserve University
EUROPEAN FUEL CELL FORUM Switzerland
European Fuel Cell Group Ltd The Netherlands
Fuel Cell Commercialization Group (FCCG)
Fuel Cells 2000
Hydrogen Energy Center (HEC)
Hydrogen Pacific
Hydrogen and Fuel Cell Investor
Hydrogen Industry Council Canada
Institute for Integrated Energy Systems - Univ. of Victoria (IESVic)
International Association for Hydrogen Energy
National Fuel Cell Research Center
National Hydrogen Association
Northeast Advanced Vehicle Consortium(NAVC)
Small-scale Fuel Cell Commercialization Group, Inc. (SFCCG)
Technology Transition Corporation
US Fuel Cell Council
World Fuel Cell Council

Source: H2fc.com

UTAH FUEL CELL ASSESSMENT

Utah is better than average when it come to a fuel cell presence in the industry. However, the State is by no means a leader in any phase of the development of fuel cells, from the production fuel cell stacks to the development of hydrogen. Utah does have a presence in these respective areas:

COMPANIES

We had the opportunity to visit each of these companies and/or speak with the respective founders. Although their technologies look promising, none of the companies is a member of any of the major fuel cell coalition or industry commercialization groups. The lack of network contacts will prevent Utah from ever being a major player in the commercialization of fuel cells with the State's existing companies. In addition, the companies seem to have a technology development focus, rather than a marketing focus. As was mentioned previously concerning technology commercialization, these companies will need to develop a complete product application for a specific market niche in order to become successful commercially.

Note: Company information and patents listed are based upon corporate websites and the USPTO

Materials and Systems Research (Private Company)
5395 West 700 South
Salt Lake City, UT 84104
Phone: (801) 530-4987
Fax: (801) 530-4820

Founders: 1990 Dr. Dinesh K. Shetty and Dr. Anil V. Virkar
Employees: 16
Patents: 2

Since 1992, MSRI has received more than 25 grants and awards in excess of $6.5 million from different government agencies, including the Department of Defense, Department of Energy, National Science Foundation, NASA, and the Advanced Technology Program at the National Institute of Standards and Technology. MSRI specializes in Solid Oxide Fuel Cells.

Ceramatec (Private Company)
2425 South 900 West,
Salt Lake City, Utah 84119
Telephone: 801-972-2455
Fax: 801-972-1925

Founded: Over 25 years old
Patents: 27 (not all fuel cell related)

Already in medical, industrial, and consumer markets, Ceramatec's focus on ion transport combines product design and manufacturing with contract R&D experience. Noiseless generation of extremely pure gases, precise metering of fluids, and clinical measurement of oxygen and toxic gases are possible with Ceramatec's products.

Powerball

2095 West 2200 South,
West Valley City, Utah 84199
(801) 974-9120

Founded: 1997 Jed Checketts
Patents: 4

Powerball Technologies, LLC is focused on innovative hydrogen distribution technologies. At the heart of their technology is the proprietary hydride pellets or Powerballs™ which increase the storage density and distribution efficiency for hydrogen through incremental and on-demand production of hydrogen for a wide range of applications from industrial hydrogen to portable fuel cell systems.

Powerball Technologies is a publicly held company and can be traded on the OTC Bulletin Board: PRBL.OB

Powerball had no revenues for the three months ended March 31, 2001 and 2000, respectively, and has had no revenues since July 9, 1997 (inception). The Company's net loss since inception has been $1,129,357. At March 31, 2001, the Company had current assets of $192,228 and current liabilities of $18,921 for working capital of $173,307. At March 31, 2001, the Company had other property and equipment of $23,989, net of depreciation, and patents and license agreements, net of amortization, of $20,639.

Cash used in operations for the three months ended March 31, 2001 was $165,681 compared to $8,080 for the three months ended March 31, 2000. Since inception the Company's operations have been funded primarily by cash received from capital contributions and the issuance of common stock for cash. [8]

[8] PowerBall International Quarterly Report – SEC Form 10QSB May 15, 2001

ACADEMICS

Dr. Anil V. Virkar –
Chair of the Materials Science & Engineering Department
College of Engineering
University of Utah
122 South Central Campus Drive Rm 304
Salt Lake City UT 84112-0560
anil.virkar@m.cc.utah.edu

Dr. Virkar is the co-founder of Materials and Systems Research and is the director for the Fuel Cell Center for Excellence for the Department of Community and Economic Development. Dr. Virkar has 23 patents issued or pending.

Dr. Dinesh K. Shetty –
Materials Science & Engineering Department
College of Engineering
University of Utah
122 South Central Campus Drive Rm 304
Salt Lake City UT 84112-0560
Dinesh.K.Shetty@mse.utah.edu

Dr. Shetty is the co-founder of Materials and Systems research. Dr. Shetty's research interests focus on advanced ceramics.

RECOMMENDATIONS

Despite the lack of network and demand for fuel cell technology in Utah, the State still has an opportunity to play a significant role in the commercialization of fuel cells. Utah does not have the tax base to provide the type of funds needed for broad research in this area, especially when one considers that fuel cells are still years away from being commercially feasible in the mainstream market. A diverse portfolio of initiatives can help the existing Utah companies to become part of the commercialization network while at the same time encouraging the major fuel cell companies to develop and/or produce here in Utah.

• **Olympic Technology Expo** – The Olympics will be a great opportunity to showcase Utah's technologies to the world. By hosting a Utah Technology Expo, little known and ignored companies could have the opportunity to gain some exposure and possibly make contacts with the various business leaders from around the world that will be attending the Games.

• **Application-Specific Fuel Cell Development** – Encourage Utah companies to develop application-specific, market-ready products by contracting with these companies to develop efficient energy applications for small state infrastructure projects (lights, road signs, etc.) Fuel cells are perfect for remote areas far from the electric power grid. This is an opportunity for rural, isolated areas to generate the power necessary for things like Smart Sites and other energy-intensive facilities. By challenging the companies to develop market-ready products the State can simultaneously encourage the companies to adopt a market focus, while at the same time solving some of its own energy concerns.

• **Focus Funds in Hydrogen Research –** The State needs to be very strategic in its appropriation of funds for research. Efficient production and storage of hydrogen continues to be the greatest hindrance to the commercialization of fuel cells. Currently, the most efficient (yet relatively inefficient) process for obtaining hydrogen is the reformation of methane. Methane can be produced from coal, of which Utah has a large amount.

No company, state, or nation has yet to become the leader in hydrogen development. The potential growth and economic benefits to the region that develops hydrogen efficiently will, by comparison, far exceed that of the OPEC nations.

• **Make Utah a Test Site for Fuel Cell Vehicles –** The State and its universities already have some ties to the auto industry. Utah needs to leverage these relationships to encourage the mass testing of fuel cell commercial passenger vehicles in the State. For instance, Utah has the famous Bonneville Salt Flats that could be used for a Fuel Cell speed record contest between fuel cell car developers.

• **Convert All State Fleets to Fuel Cells –** The quickest way to gain the attention of the fuel cell industry is to become one of its largest customers. As has been pointed out, costs can only come down if there is more production, and there cannot be production without demand. The example of SunLine Transit in California shows that such a bold move has the potential to make an organization a leader overnight. If UDOT converted all of its fleet to fuel cells, Utah would instantly attract the attention of the whole industry. The State can then partner with other companies to develop the hydrogen production/refueling infrastructure to make Utah the first region in the world where the general public drives vehicles powered by fuel cells.

• **Alternative Fuel Policy –** Just as California has created excitement in the industry, and demand in the market, with its policy to have 10 percent of California cars be zero-emissions in 2003, Utah could facilitate commercialization of fuel cells by making similar requirements. By talking about it and advocating it, Utah can become a major center for fuel cell development - something that will be attractive to many companies seeking to produce fuel cells en masse in 5 to 10 years.

Superconductors

Saving electricity, increasing reliability and capacity

> *"We believe that that future [of superconductors] looks very bright – with so many factors (load growth, sitting difficulties, demand for higher-quality, more reliable power, competition) converging to require new technology solutions to fortify the power grid".*

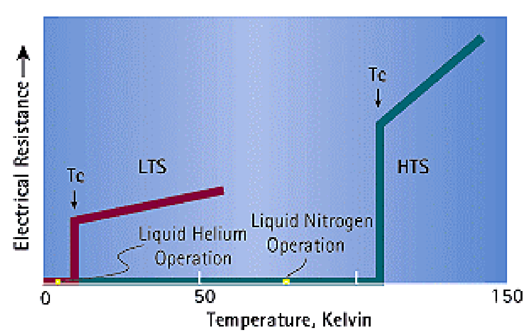
John Howe, American Superconductor

By the time electricity arrives at a residence about half of it has been lost in the transmission and distribution process. With the energy crisis taking place in California and threatening to take place in other regions of the nation, the energy lost in the transmission process is becoming more important. One solution to the transmission loss problem is the use of superconductor components in the grid system. The cost of installing superconductor components and keeping them at the right temperature is still high, but the energy savings involved with using superconductors outweigh the costs.

Description of Segment

Superconductors are chemical compounds that conduct electricity with zero resistance and are perfect conductors of electricity. Superconductors do not have any resistance to the flow of direct electrical current and have virtually no resistance to alternating electrical currents. They transmit electrical current with 100% percent efficiency, because resistive heating does not dissipate energy. Superconductor material loses all resistance when cooled below a critical temperature, which is different for each superconducting substance (American Superconductor. *Superconductivity Fact Sheet* 2001). Superconductors eliminate transmission losses and will be able to transmit as much as 100 times the current that ordinary conductors of the same size (Office of Power Delivery. 2000).

Superconductors are separated into two different classifications, low temperature superconductors and high temperature superconductors. Dutch physicist Heike Kamerlingh Onnes discovered low temperature superconductors early in the 20th century. In 1911 he discovered that mercury had no electrical resistance when cooled to 4.16 K, mercury's critical temperature.



Over the next several decades, scientists worked to develop compounds that had a higher critical temperature. Niobium and titanium alloy, which has a critical temperature of 20 Kelvin (-253^{o}C), became that base for low-temperature superconductor applications. Low-temperature superconductors are still used today in many applications, such as medical scanners and magnetic separators (BICC General. 2001).

In 1986 Alex Müller and George Bednorz discovered a new type of superconductors that operated at temperatures much higher than low-temperature superconductors. They discovered a bismuth-based, copper oxide ceramic material that had no resistance at temperatures of 35 K (-238^{o}C). This marked the discovery of high-temperature superconductors. High-temperature superconductors (HTS) were further improved in 1987 by Paul Chu at the University of Houston, who discovered a compound that conducted electricity with no resistance at 94 K (-179^{o}C). This discovery spurred more interest in pursuing commercial applications of superconductors because the new critical temperature was above that temperature of liquid nitrogen, which was inexpensive and readily available (EREN. 2001).

Researchers are working to find a less expensive superconductor material and to raise the critical temperature. Recently Akimitsu and his coworkers at Aoyama-Gakuin University in Tokyo, Japan discovered that magnesium diboride has superconductor properties at 39 K. This was a significant finding because magnesium diboride is inexpensive and readily available. Further research is being done to see whether this compound can utilized in superconductor wires (BA Glowacki. 2001).

Superconductors are no longer a scientific novelty. They are now being used for many electric applications. Superconductors are now being developed for use in several electricity grid applications, and have the potential to make the existing electric grid infrastructure more efficient and reliable. Today's aging electricity infrastructure is likely to be replaced, in part, by superconductor products that are being developed today. These products include HTS power cables, transformers, fault current limiters, motors, SMES systems, and generators. The accumulated energy savings resulting from widespread use of these superconductors application would solve today's energy crisis and make renewable forms of energy more practical (EREN. 2001).

Need to Upgrade Electricity Infrastructure

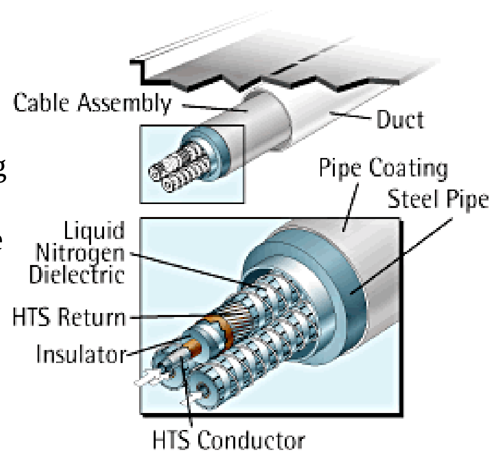
The electricity grid infrastructure is in need of being replaced and modernized. Methods of generating and delivering power that are used today date back to the early 1900s. Many components of the electricity infrastructure in the United States date back to the 1930s and are in need of replacement. In the Internet age electricity is the backbone of growing industry and technology. Urban areas are seeing growing numbers of residential consumers, and these consumers are demanding more electricity. Furthermore, business consumers are demanding more reliable sources of energy. These growths in electricity demand are causing the electricity grid to be utilized at full capacity. Renewable sources of electricity such as wind, solar, and geothermal cannot significantly help the problem due to the losses that are incurred when transmitting the electricity over long distances. The electricity infrastructure is in dire need of replacement and modernization.

High-Temperature Superconductors can be used to improve efficiency, capacity, and reliability of the electricity infrastructure. "High-temperature superconductors technology…can replace present grid segments with greatly enhanced capacity, thereby giving the grid more flexibility and reliability, along with the ability to accept cleaner new, renewable generation. Increased efficiency in generation, transmission, distribution and storage of electricity through the use of HTS would also mean that less electricity will need to be generated in the first place" (Energy Magazine 2001, pg 1) Superconductor applications have the potential to provide solutions to many of the electricity infrastructure's current limitations and problems.

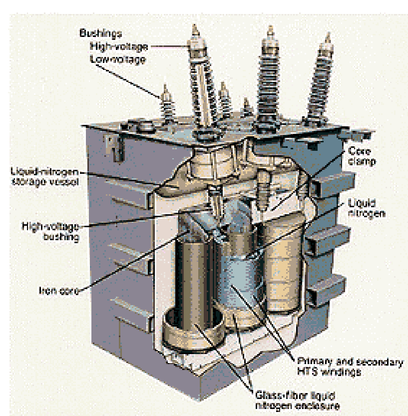
Applications

Superconductors can be used to decrease transmission losses, and to increase efficiency and output.

- **Cables –** HTS cables can replace conventional transmission cables. HTS cables can transmit three to five times more electricity that conventional copper wires. They can be installed in the place of existing underground cables in growing urban areas or used for new electricity demand. The use of HTS cables would increase overall system efficiency and reduce energy costs (Energy Magazine, 4). HTS cables are cooled by liquid nitrogen that runs through the center of the wire. (American Superconductor. Cable Fact Sheet 2001).



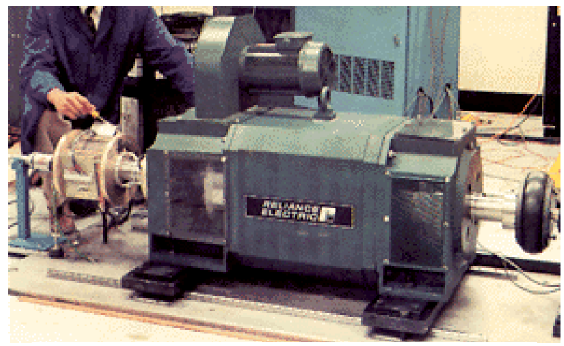
- **Transformers –** HTS transformers are lighter, cleaner, safer, and more efficient than conventional transformers. Superconductor transformers weigh 45 percent less than conventional transformers, are environmentally friendly and oil-free, run at a much lower temperature, reduce the fire hazard, and have a 20 percent lower total cost of ownership, partly due to a 30 percent reduction in total losses. (Office of Power Delivery 2001, pg 3)



Waukesh, http://www.waukeshaelectric.com/weshtspr.htm

- **Fault Current Limiters –** A fault current limiters reduces power disturbances in the electricity grid. Disturbances are caused by lighting striking, short circuits, or power fluctuations. Superconductors are naturally fault current limiters because they are able to quickly change from a "superconducting, zero impedance state to a normal high impedance state in a fault situation". Superconductor fault current limiters are better than conventional fault current limiters because they require little maintenance and do not need to be replaced after they are used (Office of Power Delivery 2001, pg 6).

- **Motors –** HTS motors can replace large industrial motors that are 1,000 hp or more. Large industrial motors of 1,000 hp or more consume more that 20 percent of all electric power produced in the United States. HTS motors can potentially increase efficiency by 98 percent, reducing electricity loss by about 50 percent (Energy Magazine 2001, pg 2).



Reliance, http://www.reliance.com/prodserv/motgen/b2776_1.htm

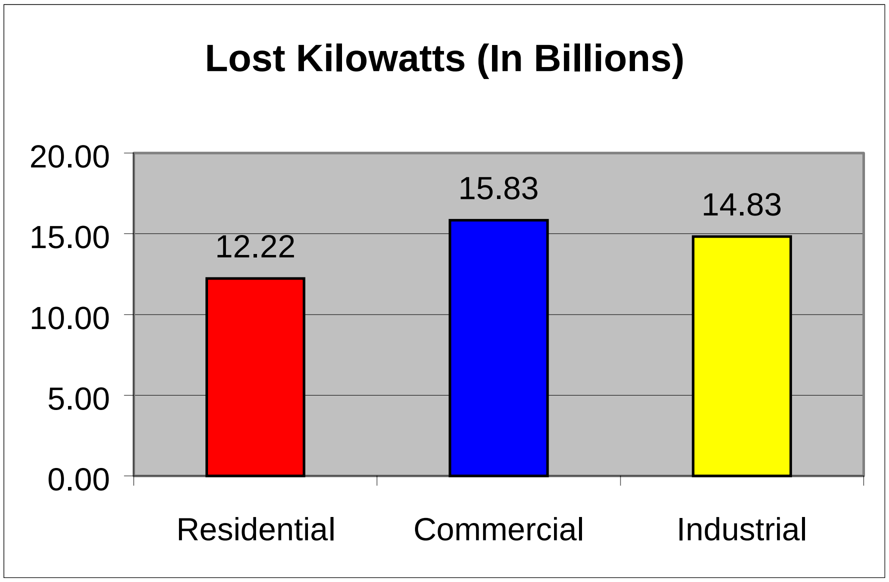
- **Generators –** Generator convert rotational energy, from a steam or gas turbine into electricity. Conventional generators lose about two percent of the electricity that they generate in the form of heat. Superconductor generators do not lose energy due to resistance and are 99.5 percent efficient. These generators have been tested successfully for power plant applications. A 1,000 MW superconductor generator (usual size for a power plant) could save four million dollars per year in reduced energy losses (Office of Power Delivery 2000, pg. 5) (American Superconductor. Generator Fact Sheet. 2001).

- **SMES System –** Superconducting Magnetic Storage Systems store energy in a superconducting magnet and are capable of releasing megawatts of electricity instantly when there are sudden losses on the grid. Grids experience more blackouts and disturbances when run at capacity during peak hours. This is particularly a problem in California where power flow is at or exceeding grid capacity and causing blackouts. Sudden drops in voltage and blackouts cause production losses for manufacturing firms. An SMES system eliminates problems with stability, and allows 15-20 percent more power to flow through existing power lines (Yurek, 2001, pg 3).

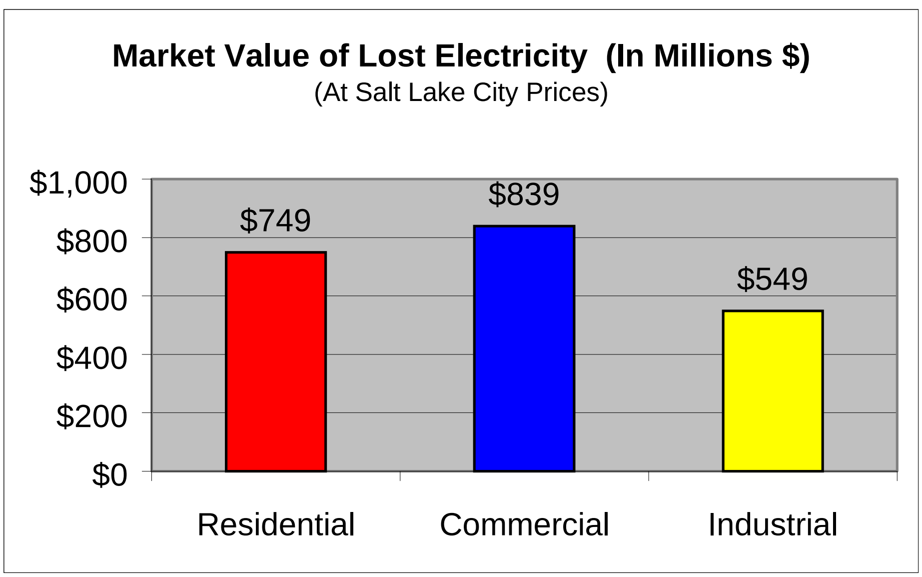
How Superconductors Can Benefit Utah

There are two issues, first how can the use of superconductors help Utah be an energy-safe state, and second what can Utah do to be a leader in superconductor research, development, and production?

Super conductors can help Utah be an energy-safe state. In the year 1999 in Utah 42.87 billion kilowatts were lost during generation, transmission, and distribution of electricity. (Energy Information Administration. 2001)



If this lost electricity were sold at today's prices in Salt Lake City it would be worth approximately $2.13 billion (Residential rate - $.061307, Commercial rate - $.053, Industrial rate - $.039).



Using superconductor cables and transformers could save a significant portion of the electricity lost in Utah. Utah would then have a larger surplus of electricity, causing the cost of electricity in Utah to be even lower and giving Utah a bigger safety net of energy for high-tech companies.

Superconductor applications are not being used in Utah's electricity grid. According to inside sources, PacifiCorp is doing nothing to develop or apply superconductors in its grid system. The main reason being that Utah has a smaller population and still has the capacity to meet the growing energy needs of its business and residents. Utah is not in crisis mode as other states are. Utah need not wait until a crisis to start making the electricity grid system more efficient.

The second issue is what can Utah do to become a world leader in the superconductor industry? Superconductors have the potential to explode in the market. Superconductor applications will be competing with conventional electricity equipment. Experts estimate that market in the United States, Japan and Europe for superconductor products in the year 2020 will be $122 billion (Energy Magazine 2001, 4). Utah could greatly benefit by bringing high-tech, high-growth superconductor companies here.

Utah would benefit economically by becoming a world leading in the superconductor research, development, and production, but it is unlikely that Utah can become grow this industry within Utah. Utah is not in the position to become a world leader in the superconductor industry. It is clear that Utah is behind other states in research, developing, and producing superconductors. There are currently no Utah companies that are developing superconductor products.

Ceramatec, a local research and development company, was working on developing superconductor products in the late 1980s and early 1990s. At this time there was great excitement over superconductors because of the discovery of high-temperature superconductors in 1986. Many companies jumped on the superconductor bandwagon, but when they saw that commercialization was much further into the future than they expected, they dropped superconductor research and development. Ceramatec was bought out by a foreign firm in the early 1990s and lost funding for the superconductor project. Since then they have done nothing with superconductors.

There are only a few superconductors experts Utah. The University of Utah has a small, but significant presence of superconductor researchers, including Dr. Mattis, and Craig Taylor. Superconductor production needs to be backed by significant research and development. The superconductor experts in Utah could benefit superconductor companies that come here. Experts and companies often form symbiotic relationships. Companies provide needed research funds for the researcher's project and in return use the results of the research for business applications.

According to Dr. Mattis, there is nothing holding Utah back from developing a superconductor industry. Getting the materials to make superconductors would not be a problem. Kennecott may even have some of the materials needed in making superconductors.

Dr. Taylor stated that the focus of moving superconductors towards commercialization should the study of cryogenics, which is the study of low-temperatures. The cost of keeping superconductors below the critical temperature is perceived to be too high. Superconductors have obvious utility in very large cities where there are massive amounts of electricity being used and congestion of electricity infrastructure, but the cost of keeping the cable below the critical temperature repels most utility companies.

HTS systems use liquid nitrogen refrigeration systems. Liquid nitrogen is inexpensive, friendly to the environment, and readily available. Also there is already large-scale liquid nitrogen production throughout the world. The liquid nitrogen refrigeration systems used with superconductor cables use about one-fourth of the energy savings that are realized, so there is still a net electricity saving. On early superconductor cable projects the cost of installing the refrigeration system has been about 10% of the total project, but even after the cost of refrigeration is taken into account superconductor cable still will save energy and money. The cost of refrigeration will go down as the process is commercialized. One reason that the cost of cooling superconductors is a barrier to entry is that the cost of cooling conventional wires is zero; any cost of cooling is perceived as too much.

Recommendations

Speaking to the issue of how Utah could save energy through the use of superconductors and have cheaper more readily available energy, we recommend two things that the state could do to encourage their use. First, the State should deregulate the energy industry. Second, the State should encourage PacifiCorp to launch a superconductor project in Utah.

As previously mentioned Utah's biggest utility company is doing nothing to take advantage of the benefits of superconductors, partly because they have little incentive to cut cost. In Utah the energy industry is regulated, the profit margin that PacifiCorp can charge is regulated by the State. PacifiCorp has little incentive to be an early mover in the use of superconductors. Its profit margins are regulated, but its costs are not. It has the money to invest better grid technology, but with a fixed profit margin it has no reason to become more cost effective.

If the State wants to become more energy efficient by upgrading its grid with superconductors the first thing it should do is allow competition and provide incentives for utility companies. One way to do this would be to deregulate the utility industry. California has been a good example of what not to do. California deregulated the wholesaler utilities market, while it did not regulate the retail utilities market. It also disallowed long term contracts between energy wholesalers and retailers, which would have stabilized utility prices. Pennsylvania on the other hand has been a good example of deregulation. It deregulated the production of electricity and the retail sale of electricity, while regulating the transmission and distribution of electricity in 1997. The price of electricity has actually gone down as companies have competed. Utah could follow this model and also offer utility companies incentives to adopt superconductor components.

The second thing that Utah could do to encourage the use of superconductors is to help launch a superconductor project in Utah, together with PacifiCorp. Recently, Pirelli (the largest cable company in the world), Detroit Edison, EPRI, the U.S. Department of Energy, and American Superconductor worked together on the Detroit HTS Cable Project installed 18 miles of superconductor wire (400 feet of actual cable) into the Detroit grid system. The project was funded in part by the U.S. Department of Energy's Superconductivity Partnership Initiative (SPI). Three superconducting cables replaced nine underground conventional cables (American Superconductor Press Release. 2001).

The State of Utah could sponsor, or encourage PacifiCorp to sponsor such a project in Salt Lake City. This will bring to light the energy savings superconductor applications create and promote the further use of superconductors in Utah. Such a project would bring the operations of superconductor manufacturers and cable companies and could be the seed for a superconductor industry in Utah.

The second question is how can Utah become a world leader in the research, development, and production of superconductors? As mentioned before, Utah is not in the position to become a world leader, but it certainly can attract or grow a small superconductor industry presence. There are several things that Utah can do to build a superconductor industry presence here.

First, the State could initiate a government project like the Detroit HTS Cable Project. Such a project would bring superconductor experts and companies to Utah.

Second, the State could target superconductor companies by using grants, contracts, and tax incentives, and by promoting Utah's favorable qualities. Bringing superconductors companies here would be a good start to building a superconductor industry presence.

Third, the State could help to initiate superconductor and cryogenics research projects at its universities. There are only a few professors in Utah's universities that are researching superconductors and cryogenics. The State could provide funds to subsidize the salaries of top superconductor and cryogenics researchers in order to attract them to Utah. Once there is a significant group of these researchers this could be used as a selling point to attract superconductor companies.

Economics of Superconductors

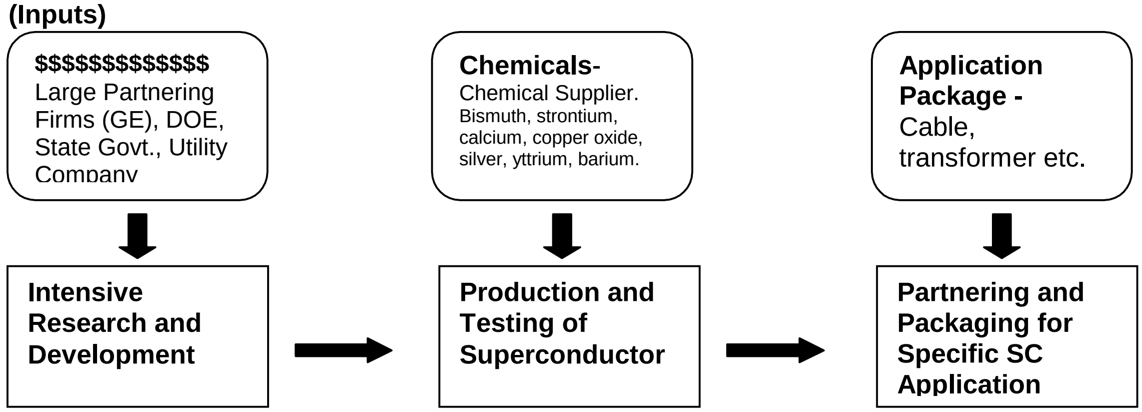
Currently the biggest input to make superconductors is research and development. The chemicals that are needed to manufacture superconductors are bismuth, strontium, calcium, copper oxide, silver, yttrium, barium and inexpensive metals. None of these materials are especially rare and work is being done to reduce the costs of the materials inputs for superconductors. Also work is being done to lower the cost of the superconductor application packages (i.e. cables, transformers, etc.). Work needs to be done in the field of cryogenics to lower the cost of keeping the superconductors below the critical temperature (Prusseit 2001).

The value chain of the typical superconductor company can be seen in the chart below. Superconductor companies partner with very large corporations that are looking to improve their products or services (cable companies and utility companies). For example, American Superconductor partnered with Pirelli, the largest cable company in the world, to construct a 400-foot superconductor cable project in Detroit. Other superconductor operations are kept under a large corporation wings. General Cable, now the biggest cable company in North America, acquired BICC Superconductors and very recently sold it to Pirelli. Many superconductor companies that are focusing on grid applications receive funding from the large corporations they partner with or from the Department of Energy.

The chemicals needed for the production of superconductors are acquired fairly easily. Superconductors are manufactured then tested for superconductivity (Prusseit 2001). Superconductor material is then passed to the company that manufactures the application. In the example above American Superconductor made that superconductor wire material then passed that material to Pirelli. Pirelli then placed the superconductor wire in the wire encasing and laid the wire in the ground. This is not the model that all companies involved in superconductor operations use.

Typical Superconductor Value Chain

(Inputs)



Superconductors add value firstly by creating materials that have zero resistance to electricity, and secondly by lowering the cost of superconductor applications. Superconductor applications have utility because the energy saving they create are now greater than that cost of installing and maintaining them. Three or four years ago it cost about $1000/kilo-amp-meter for HTS wire, today it cost $50/kilo-amp-meter. Copper cables cost $25/kilo-amp-meter (Howe. 2001).

Superconductors have many applications, but the core value for electricity application is that they save electricity. This has even more value because of energy crisis that is taking place in California and threatening to take place in other parts of the nation. Energy needs to be saved where possible and electricity infrastructure superconductor solutions save a large amount of electricity, provide greater reliability, and increase capacity.

Superconductors used for electricity applications are very new in the marketplace. Most applications are still in testing phase and it will be a few years before the mainstream market accepts them. Currently, there is a race to see who can develop the best superconductor compound and the best production method. Superconductor companies are pouring millions of dollars into research and development.

The first company that can lower the cost of producing superconductor electricity components significantly will have a huge advantage over other companies. The current cost of keeping superconductors below the critical temperature and the cost of the equipment itself are still perceived as being too high. The projects that are taking place are funding by the government. Large utility companies will be the first to adopt superconductor energy products, because they will be able to save huge quantities of electricity and billions of dollars.

As superconductor technology is adopted by utility companies and then by large manufacturing companies demand will increase. As production of superconductors increases that cost of producing them will decrease through creating economies of scale. The first company to lower the cost of production will only have an advantage if it can continue to produce superconductor products on a large scale more efficiently than other companies. There will be an advantage of learning early how to research and develop superconductors. Those companies that are developing superconductors now will be able to apply their acquired knowledge of superconductors to the production process.

Superconductor Companies

Alphabetical Listing of Superconductor Companies

The following companies are involved in the superconductor industry. (Superconductors.org, 2001)

1. **ABB Power T&D Company, Inc.** (http://www.abb.com) - Electric Utility Solutions.
2. **Air Products** (http://www.airproducts.com) - Supplier of liquid helium and nitrogen
3. **American Superconductor Corp.** (http://www.amsuper.com) - HTS Supplier for the Commercial Power Industry
4. **Applied Physics Systems** (http://www.appliedphysics.com) - SQUIDS and Superconducting Magnetometers
5. **ARS Associates** (http://www.arsassociates.com/) - Superconductor Process Equipment
6. **Australia Superconductor** (http://www.superconductors.com.au/) - Australia's leading supplier of High Temperature Superconductor products
7. **BICC General** (http://www.bicc-sc.com/) - A Pirelli Subsidiary, HTS Tapes and Cable
8. **Coating and Crystal Technology** (http://www.coatingandcrystal.com/) - Manufacturer of HTSC Substrates
9. **Conductus** (http://www.conductus.com/) - HTS RF Filters
10. **Conectus** (http://www.sofort-service.de/) - Consortium of European Companies
11. **Cryoelectra GmbH** (http://www.cryoelectra.de/) - HTS Filters, Wires and Tapes
12. **Cryomagnetics, Inc.** (http://www.cryomagnetics.com/supercon.htm) - Superconducting Magnets
13. **CSIRO Telecom** (http://www.tip.csiro.au/cscripts/relationships/render.asp?page_id=380&hist=.172&left=419) - SQUIDS & RF Filters
14. **Daesung** (http://www.daesungcable.com/english/htm/product/body_conductor.htm) - Superconducting Cable
15. **ETH Materials** (http://lomer.ethz.ch/~skoebel/hts_intro.html) - HTSC in Power Applications - Switzerland
16. **EURUS Technologies, Inc.** (http://www.teameurus.com/) - EURUS Superconductors
17. **Everson Electric Co.** (http://www.eversonelec.com/) - Superconducting Magnets and Cable-in-conduit
18. **General Atomics** (http://www.ga.com/) - HTS Current Limiters, HTS Composite Materials
19. **General Electric** (http://www.gepower.com/ips/bus_comp/pplants/generators.htm) - Developing 100 MVA HTS generators.
20. **Hypres** (http://www.hypres.com/) - Superconducting Electronics Company
21. **Intermagnetics General** (http://www.igc.com/energytech/superpower/index.htm) - Applied Superconductivity Products
22. **ISCO International** (http://www.iscointl.com/) - Superconductor-Based RF Filters
23. **Lotepro** (owned by Linde AG http://www.linde.de) - Supplier of liquid gas and superconductor refrigeration systems.

24. **Marketech** (http://www.mkt-intl.com/superconductor/index.html) - Marketech International HTSC Products
25. **Microcoating Technologies** (http://www.microcoating.com/) - Thin Film Deposition Technology
26. **Nordic Superconducting Technologies** (http://www.nst.com/)- Superconducting Tape
27. **Oxford Instruments** (http://www.oxford-instruments.com/) - LTS Superconductors
28. **Pirelli Cable** (http://www.pirelli.com/en_42//cables_systems/energy/innovation/hts_power_system.jhtml) - Superconducting Cable and Wire
29. **Power Superconductor Applications Corp.** (http://www.powersuper.com/) - Applied Cryogenics and Power Electronics
30. **Rockwell Automation/Reliance Electric** (http://www.reliance.com/) - HTS Motors.
31. **Southwire** (http://www.southwire.com/) - Superconducting Cable
32. **Sumitomo Electric Industries** (http://www.sei.co.jp/sn/materi.html) - HTSC Superconducting Wire & Magnets
33. **Superconductive Components Inc.** (http://www.superconductivecomp.com/) - High-Tc Powders and Sputtering Targets
34. **Superconductor Materials, Inc.** (http://www.scm-inc.com/) - Supplies Compounds Used to make Superconductors
35. **Superconductor Technologies** (http://www.suptech.com/) - HTS RF Filters
36. **THEVA** (http://www.theva.com/index.htm) - YBCO Thin Film Manufacturers
37. **Waukesha** (http://www.waukeshaelectric.com/) - Superconductor Transformers
38. **Wintici** (http://www.wintici.com/Home.htm) - High Temperature Superconductors in the Telecom Marketplace

Energy Superconductor Material Developers, Manufacturers

The following companies develop superconductor material

1. American Superconductor Corp. (http://www.amsuper.com) - HTS Supplier for the Commercial Power Industry
2. Australia Superconductor (http://www.superconductors.com.au/) - Australia's leading supplier of High Temperature Superconductor products
3. BICC General (http://www.bicc-sc.com/) - A Pirelli Subsidiary, HTS Tapes and Cable
4. Cryoelectra GmbH (http://www.cryoelectra.de/) - HTS Filters, Wires and Tapes
5. EURUS Technologies, Inc. (http://www.teameurus.com/)- EURUS Superconductors
6. Everson Electric Co. (http://www.eversonelec.com/) - Superconducting Magnets and Cable-in-conduit
7. Intermagnetics General (http://www.igc.com/energytech/superpower/index.htm) - Applied Superconductivity Products

8. Nordic Superconducting Technologies (http://www.nst.com/)- Superconducting Tape
9. Oxford Instruments (http://www.oxford-instruments.com/)- LTS Superconductors
10. THEVA (http://www.theva.com/index.htm)- YBCO Thin Film Manufacturers
11. Sumitomo Electric Industries (http://www.sei.co.jp/sn/materi.html)- HTSC Superconducting Wire & Magnets
12. Superconductive Components Inc. (http://www.superconductivecomp.com/)- High-Tc Powders and Sputtering Targets

Superconductor Application Companies

The following companies are developing specific superconductor applications

Cable

1. BICC General (http://www.bicc-sc.com/frames_superconduct.htm) - A Pirelli Subsidiary, HTS Tapes and Cable
2. Daesung (http://www.daesungcable.com/english/htm/product/body_conductor.htm) - Superconducting Cable
3. Pirelli Cable (http://www.pirelli.com/en_42//cables_systems/energy/innovation/hts_power_system.jhtml) - Superconducting Cables and Wire
4. Southwire (http://www.southwire.com/)- Superconducting Cable
5. Sumitomo Electric Industries (http://www.sei.co.jp/sn/materi.html)- HTSC Superconducting Wire & Magnets

Current Limiters

1. General Atomics (http://www.ga.com/)– HTS Current Limiters, HTS Composite Materials
2. Power Superconductor Applications Corp. (http://www.powersuper.com/)- Applied Cryogenics and Power Electronics
3. ABB Power T&D Company, Inc. (http://www.abb.com) - Electric Utility Solutions.

Generators

1. General Electric (http://www.gepower.com/ips/bus_comp/pplants/generators.htm) - Developing 100 MVA HTS generators.

Motors

1. Power Superconductor Applications Corp. (http://www.powersuper.com/)- Applied Cryogenics and Power Electronics

2. Rockwell Automation/Reliance Electric (http://www.reliance.com/)– HTS Motors.

SMES

1. American Superconductor Corp. (http://www.amsuper.com) - HTS Supplier for the Commercial Power Industry

Transformers

1. ABB Power T&D Company, Inc**.** (http://www.abb.com) - Electric Utility Solutions.
2. Waukesha (http://www.waukeshaelectric.com/)- Superconductor Transformers

Chemical Suppliers

1. Air Products (http://www.airproducts.com) – Supplier of liquid helium and nitrogen
2. Superconductor Materials, Inc. (http://www.scm-inc.com/) – Supplies compounds used to make superconductors
3. Lotepro (owned by Linde AG http://www.linde.de) – Supplier of liquid gas and superconductor refrigeration systems.

Superconductor Companies not Involved in Energy Applications

Of this list the following are not involved in developing or producing superconductors for energy industry applications. Most of these companies are involved in making superconductors for the wireless industry.

1. Applied Physics Systems (http://www.appliedphysics.com) - SQUIDS and Superconducting Magnetometers
2. Conductus (http://www.conductus.com/)- HTS RF Filters
3. Cryomagnetics, Inc. (http://www.cryomagnetics.com/supercon.htm) - Superconducting Magnets
4. CSIRO Telecom (http://www.tip.csiro.au/cscripts/relationships/render.asp?page_id=380&hist=.172&left=419)- SQUIDS & RF Filters
5. Hypres (http://www.hypres.com/) - Superconducting Electronics Company
6. ISCO International (http://www.iscointl.com/) - Superconductor-Based RF Filters
7. Superconductor Technologies (http://www.suptech.com/)- HTS RF Filters
8. Wintici (http://www.wintici.com/Home.htm)- High-Temperature Superconductors in the Telecom Marketplace

Target Companies

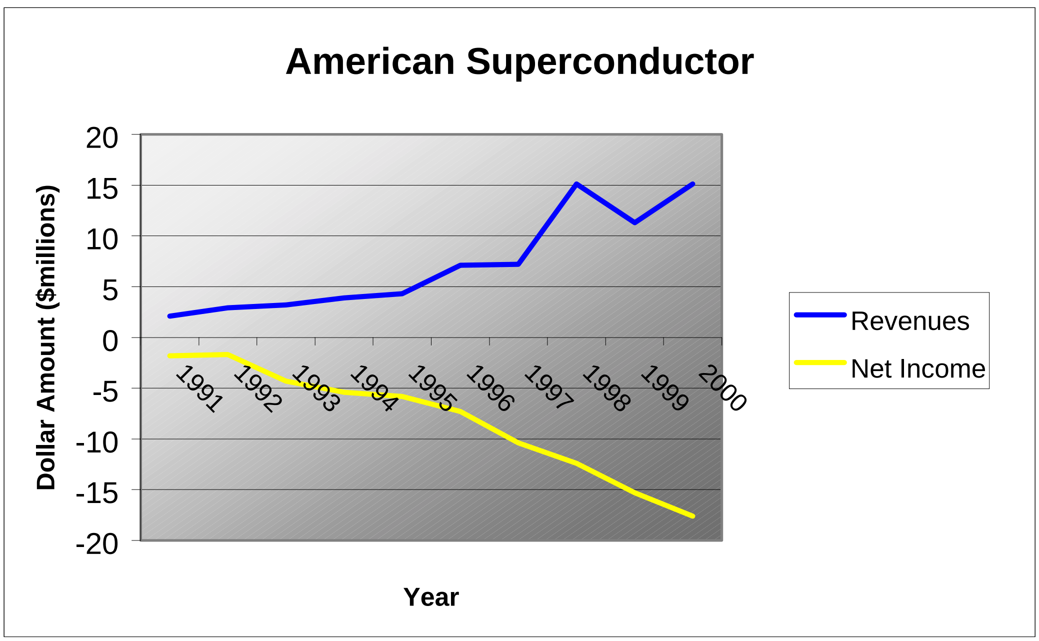
As stated previously, there are two areas in which superconductors can benefit Utah. First, Utah can use superconductors in its electricity infrastructure grid system in order to save electricity and to have a more stable, reliable grid system. Second, Utah can build a superconductor industry within the state. The following companies should be targeted.

American Superconductor

2 Technology Dr.
Westborough, MA 01581-1727
Phone: 508-836-4200
Fax: 508-836-4248
http://www.amsuper.com

American Superconductor (AMSC) is considered to be the leading superconductor developer and producer. AMSC develops superconductor materials for electric power solutions. AMSC produces superconductors for a wide range of electric power solutions, including HTS cables, generators, SMES systems, motors, and magnets. AMSC has partnered with the Department of Energy, utility companies, and large companies such as GE to develop and bring to market superconductor applications. AMSC has poured $200 million in the development of superconductor materials (Howe. 2001).

Financial Information



Type: Public

2001 Sales (mil.): $16.8
1-Yr. Sales Growth: 11.3%
2001 Net Inc. (mil.): ($21.7)
2000 Employees: 284
1-Yr. Employee Growth: 22.9%
Sales per Employee: US$59,041
Market Capitalization: 521,176,485

Stock: AMSC (NASDAQ)

Top Officers
Chairman, President, and CEO: Mr. Gregory J. Yurek, age 53, $595,000 pay
EVP and COO: Mr. Roland E. Lefebvre, age 50, $277,042 pay
SVP and Chief Technical Officer: Mr. Alexis P. Malozemoff, age 56, $211,394 pay
VP, Corporate Development, CFO, Secretary, and Treasurer: Mr. Stanley D. Piekos, age 52, $247,704 pay
VP, Electric Industry Affairs: Mr. John B. Howe, age 43
VP, Product Engineering: Mr. Robert E. Schwall
Chief Accounting Officer, Controller, and Assistant Secretary: Mr. Thomas M. Rosa, age 47
Chief Resources Officer: Mr. Ross S. Gibson, age 41, $153,662 pay
Managing Director, American Superconductor Europe GmbH: Mr. Gero G. Papst
General Manager, Strategic Programs: Mr. John D. Scudiere
General Manager, Electric Motors and Generators Business Unit: Mr. Maxwell Mulholland
General Manager, SMES Business Unit: Mr. Charles W. Stankiewicz
Manager, Human Resources: Ms. Michele Shindelman

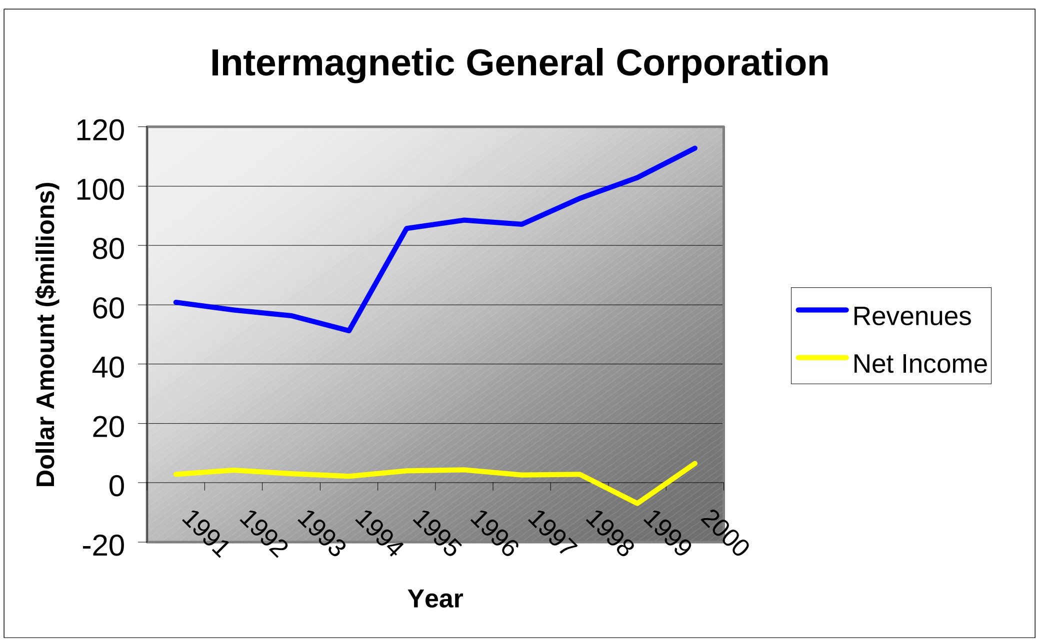
(Hoovers. 2001. American Superconductor Corporation) and (Corporate Information. 2001. American Superconductor)

Intermagnetics General Corporation (IGC)

450 Old Niskayuna Rd.
Latham, NY 12110
Phone: 518-782-1122
Fax: 518-782-7749
http://www.igc.com
http://www.igc.com/energytech/superpower/index.htm

IGC is a strong leader in developing and producing superconductors. About 60% of IGC's sales are MRI products used for medical diagnostics. IGC also develops and produces HTS for energy applications. IGC manufactures HTS material for superconductor cables, current limiters, and transformers, partnering with Southwire, General Atomics, and Waukesha Electric Systems. IGC is also involved in refrigeration applications.

Financial Information



Type: Public
2000 Sales (mil.): $112.8
1-Yr. Sales Growth: 9.6%
2000 Net Inc. (mil.): $6.5
2000 Employees: 592
1-Yr. Employee Growth: 1.5%

Market Capitalization: 517,186,772

Other Financial Information (Corporate Information. 2001)

Price/Sales Ratio 4.08
Price/Book Ratio 4.75
Price/Earnings Ratio 51.92
Price/Cash Flow Ratio 29.61
Return on Assets 7.2%
Return on Equity 9.6%
Current Ratio 3.06
Long-Term Debt/Equity 0.06
% Owned by Institutions 33.1%

Sales Analysis

During the first quarter of 2001, Intermagnetics General reported earnings per share of $0.17. This is an increase of 42% versus the first quarter of 2000, when the company reported earnings of $0.12 per share.

Inventory Analysis

As of May 2000, the value of the company's inventory totaled $22.74 million. Since the cost of goods sold was $66.25 million for the year, the company had 125 days of inventory on hand (another way to look at this is to say that the company turned over its inventory 2.9 times per year). In terms of inventory turnover, this is a significant improvement over May 1999, when the company's inventory was $26.58 million, equivalent to 152 days in inventory.

Research and Development

Research and Development Expenses at Intermagnetics General in 2000 were $6.27 million, which is equivalent to 5.6% of sales. In 2000 R&D expenditures increased both as a percentage of sales and in actual amounts: In 1999, Intermagnetics General spent $5.43 million on R&D, which was 5.3% of sales.

Financial Position

As of May 2000, the company's long term debt was $26.52 million and total liabilities (i.e., all monies owed) were $49.51 million. The long term debt to equity ratio of the company is 0.33.

(Corporate Information. Research Report: Intermagnetics General. 2001)

Stock: IMG (AMEX)

Top Officers
Chairman: Mr. Carl H. Rosner
President and CEO: Mr. Glenn H. Epstein
SVP, Finance and CFO: Mr. Michael C. Zeigler
VP and General Manager, IGC-Advanced Superconductors: Mr. Barry Gawthorpe
VP and General Manager, IGC-Magnet Business Group: Mr. Leo Blecher
VP and General Manager, IGC-Medical Advances: Mr. Richard J. Stevens
Chief Technology Officer: Mr. Ian L. Pykett
Human Resources: Mr. Joseph Smith

(Hoovers. 2001. Intermagnetics General) and (Corporate Information. 2001. Intermagnetics General)

Pirelli / BICCGeneral Superconductor

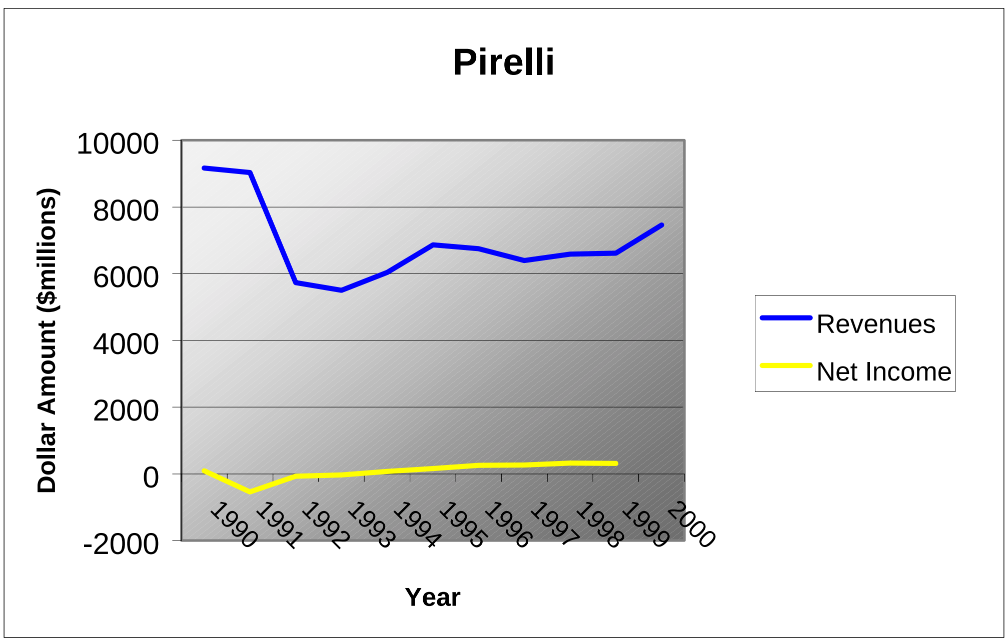
Headquarters-
Viale Sarca, 222
20126 Milan, Italy
Phone: +39-02-6442-4688
Fax: +39-02-6442-4686
http://www.pirelli.com

BICCGeneral Superconductors (Recently acquired by Pirelli)
Oak Road
Wrexham, Wales, UK LL 13 9XP
Telephone: +44 (0) 1978 662594
Fax: +44 (0) 1978 662464
http://www.bicc-sc.com

Pirelli is the biggest cable company in the world. Pirelli Cables & Systems Sector, which accounts for 60% of Pirelli's revenues, has two main divisions, Energy and Telecom. Pirelli began to research superconductors in 1987 and now is a leader in superconductor cable. Pirelli marked itself as an innovator in the superconductor cable industry, by providing the cable for the first superconductor cable to be placed in an electricity infrastructure system for Detroit Edison.

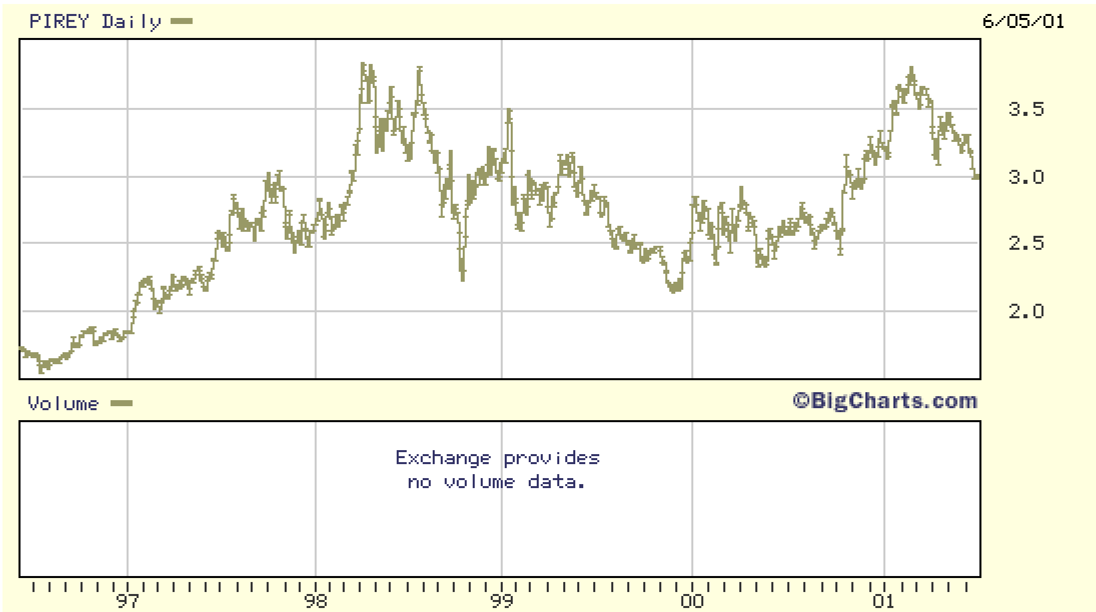
Pirelli very recently purchased BICCGeneral Superconductor from General Cable. BICCGeneral Superconductor develops and produces superconductor material. It specializes in superconductor wire and current leads.

Financial Information



Type: Public
2000 Sales (mil.): $7,024
1-Yr. Sales Growth: 6.1%
1999 Employees: 40,103
1-Yr. Employee Growth: 10.7%
Market Capitalization: 6,736,197,228

Stock: PIREY (Italy)



Top Officers
Chairman - M. Tronchetti Provera
Deputy Chairman - A. Pirelli
Managing Director - Carlo Buora
Finance Director - C. Buona
Secretary - S. Lamacchia

(Hoovers. 2001. Pirelli) and (Corporate Information. 2001. Pirelli)

Southwire -

1 Southwire Dr.
Carrollton, GA 30119
Phone: 770-832-4242
Fax: 770-832-4929
Toll Free: 800-444-1700
http://www.southwire.com

Southwire is one of the world's largest cable manufacturers. Southwire produces building wire and cable, utility cable products, industrial power cable, telecommunications cable, copper and aluminum rods, and cord products. Southwire developed and produced the first HTS power cable in the United States. Southwire successfully connected two manufacturing plants and a corporate headquarters with superconductor wire in Carrollton, Georgia. Southwire is a privately held company and is #135 on Forbes Private 500 list.

Financial Information

Type: Private
2000 Sales (mil.): $1,300.0
1-Yr. Sales Growth: (23.5%)
2000 Employees: 4,000
1-Yr. Employee Growth: (20.0%)

Top Officers
Chairman and CEO: Mr. Roy Richards Jr.
President: Mr. Stuart Thorn
COO and EVP: Mr. K. Wayne McAmis
EVP, Legal: Mr. William V. Hearnburg
CFO and VP, Finance: Mr. Franklin E. Deems
VP and Treasurer: Ms. Anna Berry
VP, Environmental and Technology Support: Mr. Lee Hunter
Asst. VP and Controller: Mr. Fred Payton
Asst. VP, Human Resources: Mr. Mike Wiggins
Director, Purchasing: Ms. Melinda Jones
Manager, Human Resources: Mr. Charles Hipps
Manager, Human Resources: Mr. Doug McKelvey

(Hoovers. 2001. Southwire.) (Corporate Information. 2001. Southwire.)

Research Groups and Institutions

1. Bar-Ilan Institute of Superconductivity - Israel
2. Center for Superconductivity Research - University of Maryland
3. Electric Power Research Inst. - Superconductors in Commercial Power Usage
4. High-Tc Superconductivity Page - Universities of Rome and Camerino - Italy
5. High-Temperature Superconductivity Research - IBM Corporation
6. Houston Advanced Research Center - Superconductor Product Testing
7. Institute for Superconducting and Electronic Materials - Australia
8. Institute for Superconductivity - University of South Carolina
9. Institute of Cryogenics and Energy Research - UK
10. Kamerlingh Onnes Laboratory - Leiden University - Netherlands
11. NASA's MIDAS Project - Superconductor Behavior in Space
12. Quantum Chaos and Superconductivity - Northeastern University
13. Rapid Single-Flux Quantum Laboratory - State University of New York
14. Superconducting Stripes - La Sapienza University - Italy

15. Superconductive Fault Limiter Research - Center for Low-Temperature Research - France
16. Superconductivity Applications Page - Argonne National Labs
17. Superconductivity at Rochester - University of Rochester
18. Superconductivity Group at UiO - University of Oslo - Norway
19. Superconductivity Research Group - Univ. of Cambridge - UK
20. Superconductor Behavior at High Pressures - Carnegie Institute - Washington
21. SUPRA - International Energy Agency
22. Swedish Superconductivity Consortium - Chalmers University - Sweden
23. Texas Center for Superconductivity - University of Houston
24. The European Network for Superconductivity - SCENET - Italy/Europe
25. The Lemberger Superconductivity Lab - Ohio State Univ.
26. Weizmann Institute of Science - Superconductivity Group – Israel

(Superconductors.org. 2001)

National Laboratories

1. Los Alamos National Laboratory
High-Temperature Superconductor/ Electrical Characterization Laboratory Contact: 505-667-3656
J. Yates Coulter
STC
Mail Stop: K763
Fax 505-665-8601
E-mail Address: jycoulter@lanl.gov
http://w10.lanl.gov/orgs/citpo/DTIN/open/UsrFac/userfac24.html

2. **Oak Ridge National Laboratory**
Fusion Energy Division
P.O. Box 2008
Oak Ridge, TN 37831
(865) 574-0988 (865) 576-7926
milorasl@ornl.gov
http://www.ornl.gov/
http://www.ornl.gov/fed/fedhome.html

3. **Sandia National Laboratory**
http://www.sandia.gov/Main.html

Conclusion

Or, Getting Started

Utah is only beginning to understand its potential for growth in the high-tech sector. Achieving the State's goals, however, will take an awesome amount of power—and power is what we will have to build.

Utah has a comparative advantage in energy production. Utah does not have a strong presence of alternative energy researchers or companies. It is not positioned to become a world leader in the alternative energy industry. However, Utah does have a comparative advantage in providing coal-fired power. The top coal combustion researchers in the world are in Utah. Utah also has a vast coal reserve. Coal reserves in Utah would last 400 years if current levels of coal extraction were held constant. Although Utah has these resources, they are not being utilized. Utah's utilities are regulated and have no incentive to build more coal-fired power plants.

The State of Utah needs to deregulate the utilities industry, activating market incentives. As result of deregulation the market will give incentive to lower energy producing cost. Coal-fired power generation will improve and cost effective alternative energy technologies will flourish. For this to happen the State must first, create an atmosphere friendly to innovation, research and development of new technologies and second, the State must promote itself as an energy-safe state. As alternative sources of energy technologies are commercialized Utah should use these sources along with its coal resources to bring inexpensive, abundant energy to all companies that want to be in Utah.

Plan of Action

Utah's Plan of action should include:

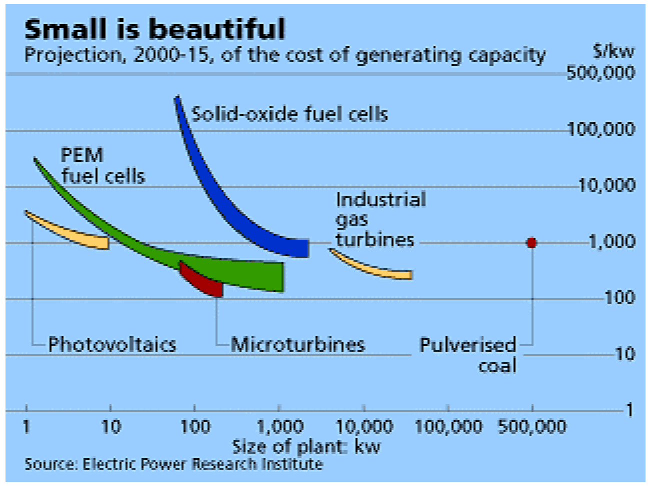
- Energy as a Comparative Advantage
- Alternative Energy Technology Exposition During the Olympics
- Office of Energy Services, Utah Department of Energy Instituting Application-Specific Projects
- Diversification of State Energy Portfolio
- Deregulation
- Tax Relief for Construction
- Tax Relief for Alternative Energy Users
- Utah Executive Agency Integration—A Comprehensive Economic/Environmental/Energy Plan

Appendix A

	FUEL CELL TYPE			
	POLYMER ELECTROLYTE MEMBRANE	PHOSPHORIC ACID	CARBONATE	SOLID OXIDE
Electrolyte	Ion Exchange Membrane	Phosphoric Acid	Alkali Carbonates Mixture	Yttria Stabilized Zirconia
Operating Temp. °C	80	200	650	1,000
Charge Carrier	H^+	H^+	$CO_3^=$	$O^=$
Electrolyte State	Solid	Immobilized Liquid	Immobilized Liquid	Solid
Cell Hardware	Carbon- or Metal-Based	Graphite-Based	Stainless Steel	Ceramic
Catalyst	Platinum	Platinum	Nickel	Perovskites
Cogeneration Heat	None	Low Quality	High	High
Fuel Cell Efficiency, %LHV	<40	40-45	50-60	50-60

Source: Fuel Cell Commercialization Group, "What is a Fuel Cell?" – 1999 http://www.ttcorp.com/fccg/

Appendix B


Small is beautiful
Projection, 2000-15, of the cost of generating capacity
$/kw
500,000
100,000
10,000
1,000
100
10
1
Solid-oxide fuel cells
PEM fuel cells
Industrial gas turbines
Photovoltaics
Microturbines
Pulverised coal
1
10
100
1,000
10,000
100,000
500,000
Size of plant: kw
Source: Electric Power Research Institute

Appendix C - PEM fuel cell component industries and relative cost breakdown

INDUSTRY	SIC CODES	FUEL CELL COMPONENT	% of COST
Plastic Products	1611-1631; 1699		
		fuel cell membrane	**26.8%**
		catalyst processor	**5.8%**
		hydrogen storage tanks	**10.7%**
		fuel cell system housing	1.0%
Machine Shop	3081		
		graphite plates	**11.7%**
		stack manufacturing	**7.7%**
		fuel cell end plates	**6.2%**
Heating Equipment	3071		
		heat pipes	**11.7%**
		electric blanket	0.4%
Electrical and Electronics	3352; 3359; 3371; 3399		
		assembly	5.3%
		microprocessor control	2.7%
Metal Plumbing and Valves	3091; 3092		
		H2 regulator	0.7%
		shut-off valves	0.7%
		air regulator	0.5%
		water recovery system	0.3%
		N2 regulator	0.3%
Adhesives	3792		
		coatings	1.5%
Other Mineral Products	3599		
		graphite products	1.5%
Compressor, Pump, Fan	3191		
		air supply blower	1.0%
		air cooling fan & ventilator	0.3%
Energy Wire and Cable	3381		
		wiring	1.0%
Plate Work	3022		
		N2 purge for storage	0.5%
Refrigeration and AC	3121		
		plastic tubing	0.3%
Indicating Instruments	3911		
		instrumentation	0.3%
Other			1.2%
TOTAL % of COST			100.0%

Source: KPMG Project Report. Estimated Economic Impacts and Market Potential Associated With the Development and Production of Fuel Cells in British Columbia. March 1996

Appendix D

HYDROGEN GENERATION PROCESSES	
TYPE	**DESCRIPTION**
Fossil Fuel Based Hydrogen Production	A closer look at the chemical formula for any fossil fuel reveals that hydrogen is present in all of the formulas. The trick is to remove the hydrogen safely, efficiently and without any of the other elements present in the original compound. The fossil fuel that has the best hydrogen to carbon ratio is natural gas or methane(CH_4).
Steam Reforming of Natural Gas	Hydrogen production from natural gas commonly employs a process known as steam reforming. Steam reforming of natural gas involves two steps. The initial phase involves rendering the natural gas into hydrogen, carbon dioxide and carbon monoxide. This breakdown of the natural gas is accomplished by exposing the natural gas to high temperature steam. The second phase of steam reforming consists of creating additional hydrogen and carbon dioxide by utilizing the carbon monoxide created in the first phase.
Electrolysis	Electrolysis is the technical name for using electricity to split water into its constituent elements, hydrogen and oxygen. The splitting of water is accomplished by passing an electric current through water. Relative to steam reforming, electrolysis is very expensive. The electrical inputs required to split the water into hydrogen and oxygen account for about 80% of the cost of hydrogen generation.
Photoelectrolysis	Photoelectrolysis, known as the hydrogen holy grail in some circles, is the direct conversion of sunlight into electricity. Photovoltaics, semiconductors and an electrolyzer are combined to create a device that generates hydrogen. Much of the research in this field takes place in Golden, Colorado at the National Renewable Energy Laboratory.
Photobiological	Photobiological production of hydrogen involves using sunlight, a biological component, catalysts and an engineered system. Specific organisms, algae and bacteria, produce hydrogen as a byproduct of their metabolic processes. Currently, this technology is still in the research and development stage and the theoretical sunlight conversion efficiencies have been estimated up to 24%.
Biomass Gasification and Pyrolysis	Biomass is first converted into a gas through high-temperature gasifying, which produces a vapor. The hydrogen rich vapor is condensed in pyrolysis oils and then can be steam reformed to generate hydrogen. This process has resulted in hydrogen yields of 12% - 17% hydrogen by weight of the dry biomass.

Source: FuelCellstore.com

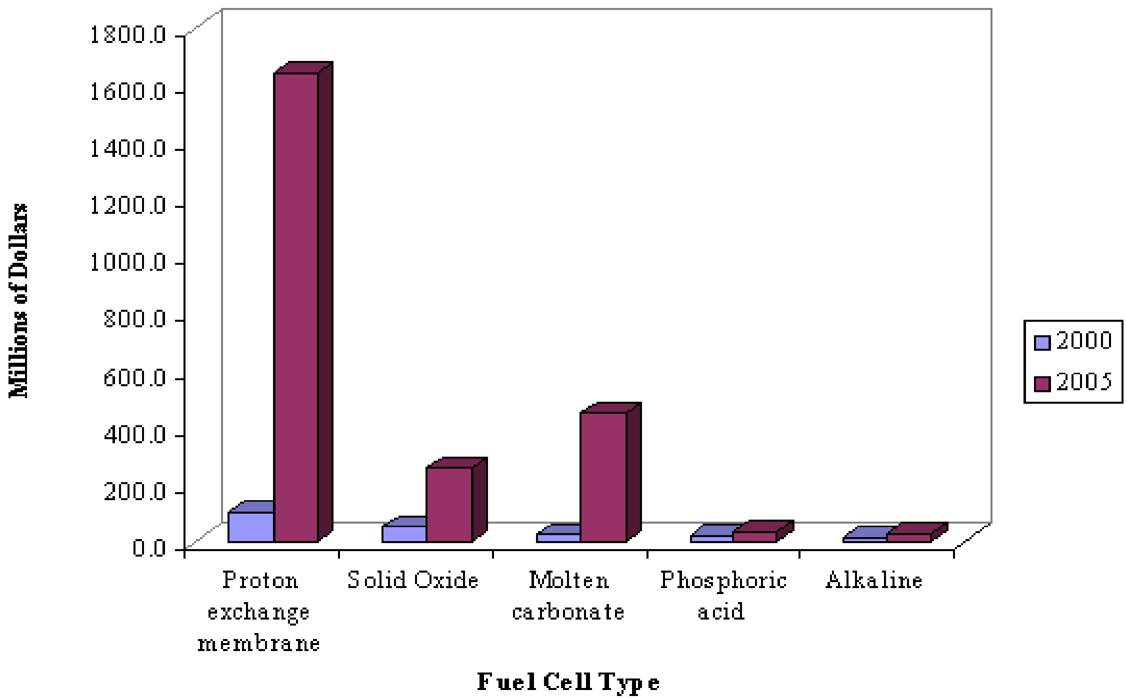
Appendix E

ELECTRIC, HYBRID ELECTRIC AND FUEL CELL VEHICLES CURRENTLY AVAILABLE IN U.S. MARKETS AND ANNOUNCED DATES OF PRODUCTION PROTOTYPES				
			Production Prototype Availability Dates	
MANUFACTURER	**CURRENTLY AVAILABLE ELECTRIC VEHICLES**	**CURRENTLY AVAILABLE HYBRID ELECTRIC VEHICLES**	**HYBRID ELECTRIC VEHICLES**	**FUEL CELL VEHICLES**
DaimlerChrysler	Epic minivan	--	ESX3, Durango	Gasoline: 2010 Hydrogen or Methanol: 2004
Ford	Ranger pickup Th!nk	--	Prodigy	2004
GM	EV1 two seater S-10 pickup	--	2001: Precept	2004
Honda	--	Insight	--	2003
Nissan	Altra minivan	--	-- [a]	2005
Toyota	RAV 4 sport utility	--	2000[b]	2003

[a]A Nissan hybrid electric vehicle became available in Japan in 1999. There is no date announced for release to the U.S. market.
[b]The Toyota Prius hybrid electric vehicle, already being marketed in Japan, will be available to U.S. buyers in the summer of 2000.
Source: National Alternative-Fuels Hotline, www.afdc.doe.gov/pdfs/my00.pdf.

Appendix F

U.S. sales of fuel cell by type, 2000-2005



Source: Business Communications Company Inc.

Appendix G

FUEL CELL PRODUCERS

Acumentrics Corporation, Massachusetts, USA (SOFC)
AlliedSignal Aerospace Co., California, USA (PEM and SOFC)
American Fuel Cell Corp., Massachusetts, USA (PEM)
Anuvu Incorporated, California, USA (PEM)
Argonne National Laboratory, Illinois, USA (PEM, MCFC and SOFC)
Avista Laboratories, Washington, USA (PEM)
Azienda Energetica Municipale (AEM spa Milano), Milano, ITALY (PAFC)
Ball Aerospace & Technologies Corp., Colorado, USA
Ballard Generation Systems, Inc., New Jersey, USA (PEM)
Ballard Power Systems, Inc., British Columbia, CANADA (PEM)
BCS Technology, Inc., Texas, USA (PEM)
Case Western Reserve University, Ernest B. Yeager Center, Ohio, USA (PEM)
Celsius, Malmo, SWEDEN (PEM)
Ceramatec, Utah, USA (SOFC)
Ceramic Fuel Cells Ltd., Victoria, AUSTRALIA (SOFC)
Consejo Superior de Investigaciones Cientificas, Madrid, SPAIN (PEM, MCFC, SOFC)
Coval H2 Partners, California, USA (PEM)
CSIRO Energy Technology, New South Wales, AUSTRALIA
DAIS Corporation, Florida, USA (PEM)
DCH Technology, Inc., California, USA (PEM)
DE NORA s.p.a., ITALY (PEM)
dmc-2 (Degussa Metals Catalysts Cerdec), Michigan, USA (PEM)
Desert Research Institute, Nevada, USA (PEM, PAFC)
Draeger Safety, Colorado, USA (PEM)
EBARA Ballard Corporation, Tokyo, JAPAN (PEM)
Electric Auto Corporation, Florida, USA (AFC)
Electric Power Research Institute, California, USA (PAFC and MCFC)
Electro-Chem-Technic, Oxford, UNITED KINGDOM (PEM, PAFC)
ElectroChem, Inc., Massachusetts, USA (PEM)
Element 1 Power Systems Inc., California, USA
Elf Atochem North America, Pennsylvania, USA (PEM)
Emprise Corporation, Georgia, USA
Energia Ltd., Virginia, USA
Energy Partners, L.C., Florida, USA (PEM)
Energy Related Devices, New Mexico, USA (PEM)
Energy Research Corporation (as of 9/2, FuelCell Energy), Connecticut, USA (DFC and MCFC)
E-TEK, Inc., Massachusetts, USA
Energy Ventures Inc., Ottowa, Ontario, CANADA (DMFC)
ETH Ceramics, Zurich, SWITZERLAND (SOFC)
Federal Energy Technology Center, West Virginia, USA (MCFC and SOFC)
FEV Motorentechnik GmbH, GERMANY (PEM, SOFC)

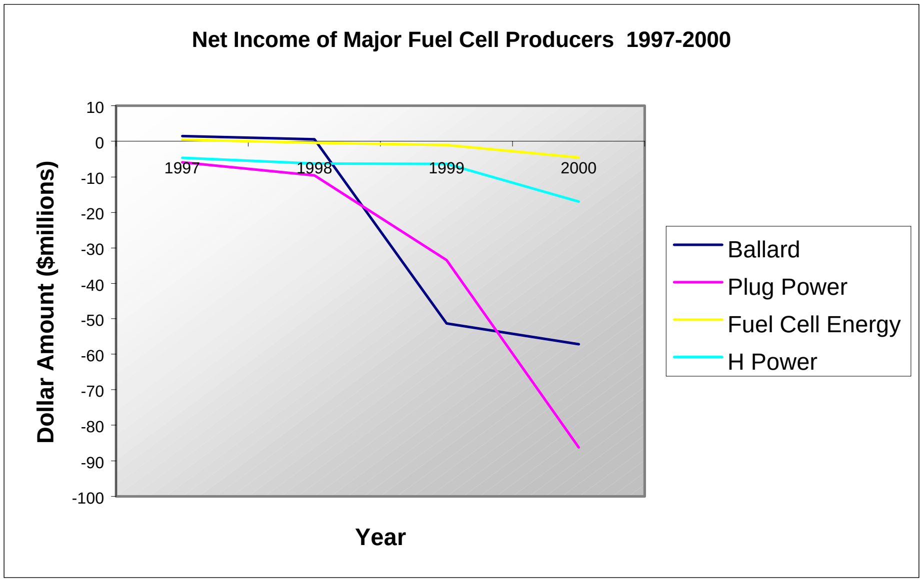
Appendix G cont.

Florida Solar Energy Center, Florida, USA (PEM)
Forschungszentrum Julich, GERMANY (DMFC, SOFC & PEM)
Fuel Cell Group, DENMARK (PAFC, MCFC and SOFC)
Fuel Cell Resources Inc. - Georgia, USA (PEM membranes)
Fuel Cell Technologies, Ltd., Ontario, CANADA
Gas Technology Institute, Illinois, USA (MCFC, PAFC, , PEM and SOFC)
Gaskatel GmbH, Kassel, GERMANY (AFC & PEM)
Gaz De France, La Plaine, FRANCE (PAFC, PEMFC, SOFC)
GE Energy and Environmental Research Corp., California, USA (PEM, MCFC, SOFC)
Global Thermoelectric Inc., CANADA (SOFC)
H Power, New Jersey, USA (PEM)
Hitachi Works, Ibaraki, JAPAN (MCFC)
H-Tec - Wasserstoff-Energie-Systeme GmbH, Luebeck, GERMANY (PEM)
Hydro Quebec Research Institute, Quebec, CANADA
Hydrocell U.K., UNITED KINGDOM (AFC, PEM)
Hydrogenics Corporation, Toronto, CANADA
Hydrovolt Energy Systems, California, USA (SOFC)
ICP-CSIC, Madrid, SPAIN
ICTP-CSIC, Madrid, SPAIN (PEM)
ICV-CSIC, Madrid, SPAIN (SOFC)
IdaTech, Oregon, USA (PEM)
InnovaTek, Inc., Washington, USA
International Fuel Cells, Connecticut, USA (PAFC and PEM)
Ion Power, Inc., Delaware, USA (PEM)
Japan Automobile Research Institute, Inc., JAPAN (PEM)
JLG Industries, Pennsylvania, USA (PEM)
Lawrence Berkeley Laboratory, California, USA (PEM)
Lawrence Livermore National Laboratory, California, USA
Los Alamos National Laboratory, New Mexico, USA (PEM)
Lund Institute of Technology, Lund, SWEDEN (SOFC)
Lynntech, Inc., Texas, USA (PEM)
Manhattan Scientifics Inc., New Mexico, USA (PEM)
Massachusetts Institute of Technology, Massachusetts, USA (PEM, SOFC)
Materials and Electrochemical Research Corporation, Arizona, USA (PEM)
Materials and Systems Research, Inc., Utah, USA (SOFC)
McDermott Technology, Inc., Ohio, USA (PEM, SOFC)
Mitsubishi Electric Corporation, JAPAN (PAFC)
Mitsubishi Heavy Industries, Inc., New York, USA (PEM & SOFC)
MTU Friedrichshafen GmbH, GERMANY (MCFC)
More Energy Ltd., ISRAEL (PEM)
National Aeronautics and Space Administration, Ohio, USA (regenerative FCs)
National Aerospace Laboratory, JAPAN (PEM)
National Fuel Cell Research Center, California, USA

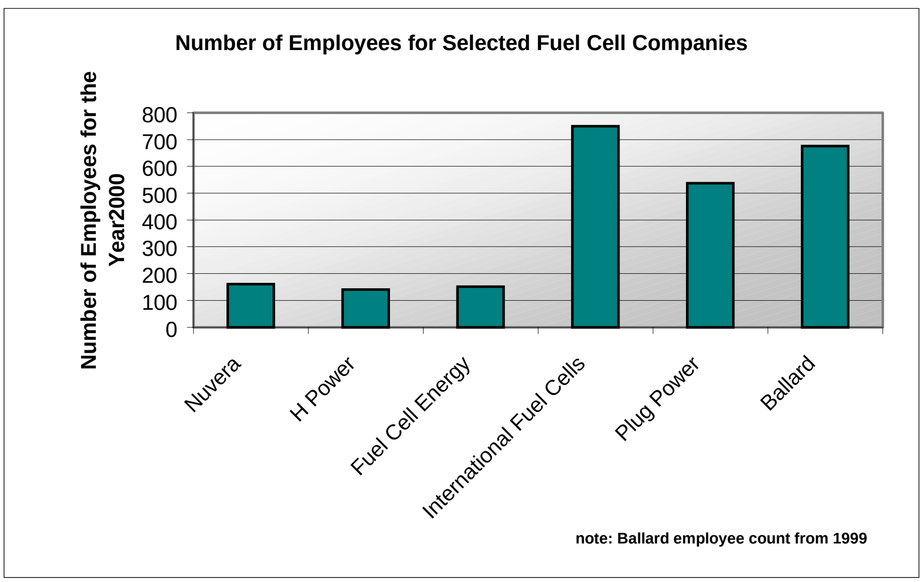
Appendix G cont.

National Renewable Energy Lab, Colorado, USA (PEM)
Netherlands Energy Research Foundation, NETHERLANDS (PEM, MCFC and SOFC)
NexTech Materials, Ltd., Ohio, USA (PEM & SOFC)
Noguchi Institute, JAPAN (PEM)
ONSI Corporation, Connecticut, USA (PAFC)
Ontario Hydro Technologies, Ontario, CANADA (SOFC)
Pacific Northwest National Laboratory, Washington, USA (PAFC, MCFC and SOFC)
Phoenix Fuel Cell Systems, Arizona, USA (PEM, SOFC)
Plug Power, LLC, New York, USA (PEM)
Procyon Power Systems, Inc., California, USA (AFC, PEM)
Proton Energy Systems, Connecticut, USA (PEM, Regenerative)
Proton Motor GmbH - Starnburg, GERMANY (PEM)
Refrac Systems, Arizona, USA
Rocky Mountain Institute, Colorado, USA (PEM)
Sandia National Labs, New Mexico, USA
Schafer Corporation, California, USA (PEM)
Schatz Energy Research Center (SERC), California, USA (PEM)
Siemens AG, Erlangen, GERMANY (PEM)
South Coast Air Quality Management District, California, USA (PAFC, PEM)
Southeastern Technology Center, Georgia, USA (PEM)
Southern States Power Co., Louisiana, USA (PEM)
Southwest Research Institute, Texas, USA (PEM)
Sulzer Hexis Ltd., SWITZERLAND (SOFC)
TATA Energy and Resources Institute (TERI), INDIA (MCFC)
TNO Energy & Environment, Apeldoorn, NETHERLANDS (PEM)
Toshiba Corporation, Yokohama, JAPAN (PAFC and PEM)
Toyota Motor Corporation, JAPAN (PEM)
United States Department of Energy, Washington D.C., USA (PAFC, PEM, MCFC and SOFC)
United States Department of Energy (Office of Transportation Technologies), Washington D.C., USA (PAFC and PEM)
United Technologies Research Center (UTRC), Connecticut, USA (PAFC and PEM)
VTT Chemical Technology, FINLAND (PEM)
Warsitz Enterprises, California, USA (PEM)
Westinghouse Savannah River Company, Georgia, USA (PEM, SOFC)
Worchester Polytechnic Institute, Massachusetts, USA (PEM)
XCELLSIS, Kirchheim/Teck-Nabern, GERMANY (PEM)
ZeTek Power PLC, London, ENGLAND (Alkaline)
Zevco, Kent, UNITED KINGDOM (AFC)
ZSW, Center for Solar Energy & Hydrogen Research, Ulm, GERMANY (PEM, MCFC and SOFC)
Source: Fuel Cells 2000

Appendix H

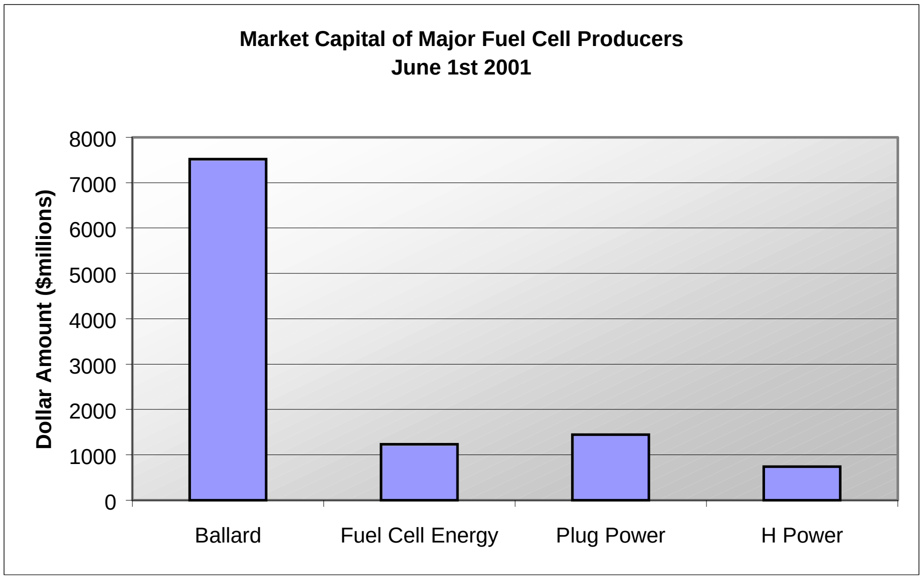


Net Income of Major Fuel Cell Producers 1997-2000
Dollar Amount ($millions)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1997
1998
1999
2000
Year
Ballard
Plug Power
Fuel Cell Energy
H Power

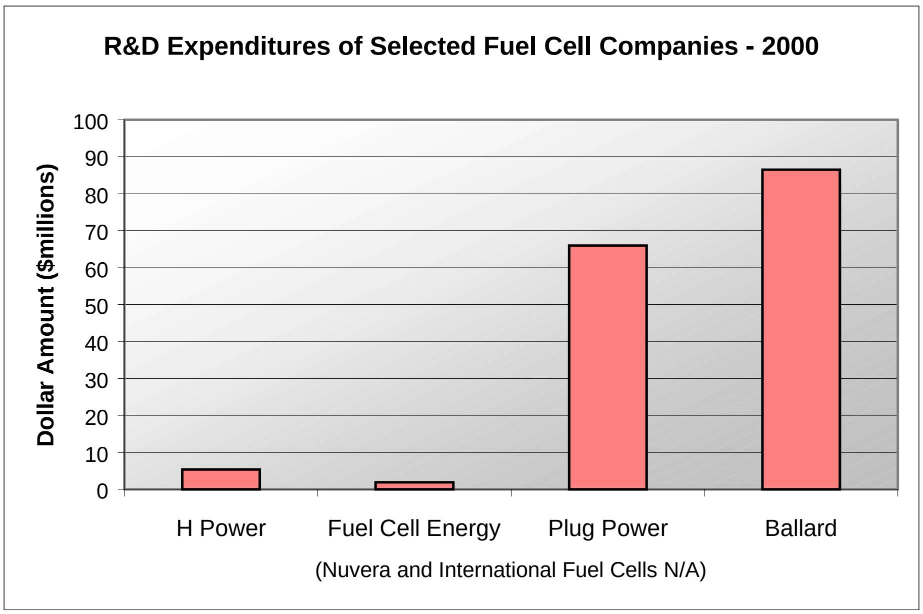


Number of Employees for Selected Fuel Cell Companies
Number of Employees for the Year2000
800
700
600
500
400
300
200
100
0
Nuvera
H Power
Fuel Cell Energy
International Fuel Cells
Plug Power
Ballard
note: Ballard employee count from 1999

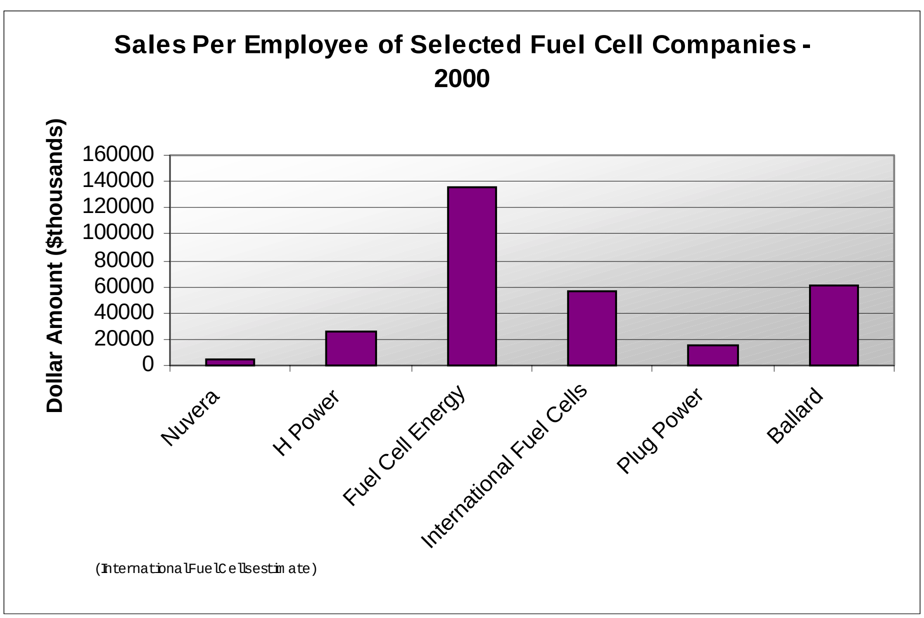
Appendix I



Market Capital of Major Fuel Cell Producers
June 1st 2001
Dollar Amount ($millions)
8000
7000
6000
5000
4000
3000
2000
1000
0
Ballard
Fuel Cell Energy
Plug Power
H Power



R&D Expenditures of Selected Fuel Cell Companies - 2000
Dollar Amount ($millions)
100
90
80
70
60
50
40
30
20
10
0
H Power
Fuel Cell Energy
Plug Power
Ballard
(Nuvera and International Fuel Cells N/A)



Sales Per Employee of Selected Fuel Cell Companies - 2000
Dollar Amount ($thousands)
160000
140000
120000
100000
80000
60000
40000
20000
0
Nuvera
H Power
Fuel Cell Energy
International Fuel Cells
Plug Power
Ballard
(International Fuel Cells estimate)

Appendix J

<table>
<tr><td colspan="2">CALIFORNIA FUEL CELL PARTNERSHIP</td></tr>
<tr><td>Fuel Cell Partners
Ballard Power Systems
International Fuel Cells
DaimlerChrysler
Ford Motor Company
General Motors
Honda
Hyundai
Nissan
Toyota
Volkswagen
XCELLSiS
Exxon-Mobil</td><td>Fuel Partners
BP
ExxonMobil
Shell Hydrogen
Texaco</td></tr>
<tr><td>Government Partners
California Air Resources Board
California Energy Commission
South Coast Air Quality Management District
U.S. Department of Energy
U.S. Department of Transportation</td><td>Associate Partners Fueling Infrastructure
Air Products and Chemicals, Inc.
Hydrogen Burner Technology
Methanex
Pacific Gas and Electric
Praxair
Proton Energy Systems, Inc.
Stuart Energy Systems</td></tr>
<tr><td>Bus Demonstration
AC Transit Agency
SunLine Transit Agency</td><td>Government Research Institutes
Advanced Vehicle Development: Fuel Cell Bus Program, Georgetown University -- www.georgetown.edu/facilities/fuelcellbus
Desert Research Institute -- www.dri.edu/Projects/Energy/Efforts.html
Fuel Cell Vehicle Modeling Program, University of California, Davis -- http://fcv.ucdavis.edu
Institute of Transportation Studies, University of California, Davis -- http://www.engr.ucdavis.edu/~its</td></tr>
<tr><td colspan="2">Government
Los Alamos National Laboratory -- www.education.lanl.gov/resources/fuelcells
South Coast Air Quality Management District -- www.aqmd.gov
State of Hawaii Energy Resources and Technology Division -- www.state.hi.us/dbedt/ert/activitybook/fs-fuelcell.html
U.S. Department of Energy, Office of Transportation Technologies -- www.ott.doe.gov</td></tr>
</table>

Source: California Fuel Cell Partnership - fuelcellpartnership.org

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